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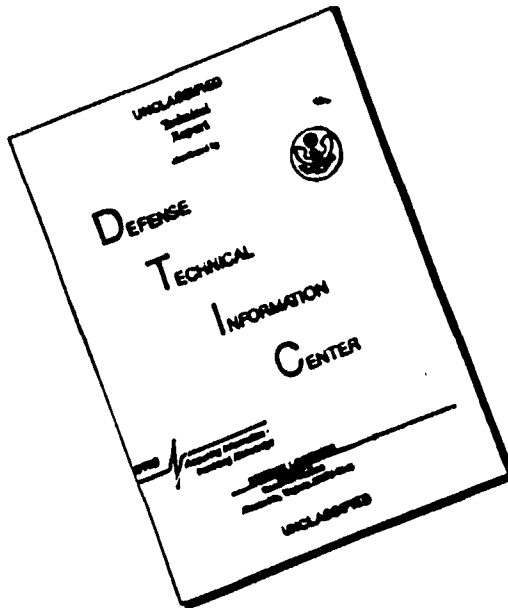
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TRANSLATIONS ON COMMUNIST CHINA'S SCIENCE AND TECHNOLOGY

No. 26

(Articles from Science Bulletin, No 12, 1962)

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TRANSLATIONS ON COMMUNIST CHINA'S SCIENCE AND TECHNOLOGY

No 26

(Articles from Science Bulletin, No 12, 1962)

This serial publication contains summaries or translations (as indicated) of selected articles on Communist China's science and technology, on the specific subjects reflected in the table of contents. Articles in this report are all from the Chinese-language periodical, K'o-hsueh T'ung-pao (Science Bulletin), Peiping, No 12, December 1962. Complete bibliographic information accompanies each article.

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[Following is a translation of the table of contents of the Chinese-language periodical, K'UO-HSUEN TIUNG-PAO (Science Bulletin), No 12, Peiping, December 1962. In some cases, a translation of excerpts from the article concerned is also included.]

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Bibliography

Huang Su-han (7806, 2976, 3352), "Micro-wave Solid Quantum Amplifier," 1960.

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SOLID STATE PROCESSING IN FLUIDIZATION SYSTEMS

Following is a translation of an article by Ch'en Hin-heng (7115 2434 1954), Lin-tung Institute of Chemical Engineering; Yuan Wei-s'ang (5913 3862 1660), Peiping Institute of Chemical Engineering; and Ch'en Liang-heng (7115 5328 1854), Shanghai Normal College; in the Chinese-language periodical, K'o-hsueh Shih-pao (Science Bulletin), Peiping, No. 12, December 1962, pages 46-51.

(A)

For solid phase processing in fluidization systems, the distribution of stopping time and the distribution of grain size of solid particles are two very important and prominent factors in macroscopic dynamics. In reports I, II, and III, the authors considered, under general conditions, the distribution of the stopping time of the solid particles and its affect on solid phase processing. Until now little research has been done on the effect of distribution of grain size. The few articles on this subject were published only when definite result were obtained. In this article the effect of distribution of grain size in single layer fluidization systems is analyzed theoretically, and it can be used as a theoretical foundation for further experimental research.

(B)

The distribution of the grain size of the solid material treated industrially is broad. Therefore, the final conversion rate of the material should depend on the two dimensional distributions, $f(\tau, z)$ of stopping time and grain size (τ is stopping time and z is grain size -- linear dimension of the particle). If the other conditions are fixed the dynamics of the process is

$$I = \phi(\tau, z) \quad (1)$$

where I is the unconversion rate of the material. Thus the statistical mean value of final unconversion rate is

$$I_0 = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \phi(\tau, z) f(\tau, z) d\tau dz \quad (2)$$

(Note: In physical meaning the lower limit of integration should be zero, and the upper limit of integration of z should be z_{\max} (z_{\max} is the largest diameter of the particle in the system). However, since $\tau \leq 0$, $z \leq 0$, and $z \geq z_{\max}$ making the distribution density zero, we should use the usual limits of integration. Same is applied to all that follows.)

The effect of the grain size on dynamics is shown in $\phi(\tau, z)$; while the effect of the layer separation phenomena (See note) on stopping time is shown in $f(\tau, z)$. When τ and z are two random variables of probability, the equation (2) can be written

$$I_0 = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \phi(\tau, z) f(\tau|z) q(z) d\tau dz \quad (3)$$

where $q(z)$ is the distribution density of the grain size of the material; $f(\tau, z)$ is the density of the stopping time distribution to the conditional distribution of z . (Note: In this article the layer separation is defined broadly. It is defined to include the heterogeneity of motion due to the difference of grain size, such as layer separation in the usual sense, mixing, etc.)

If the distribution of grain size is not counted, the mean unconversion rate is calculated from the actual dynamic function, $\psi(\tau)$, of the mixed particles combined with the stopping time distribution function, $f_1(\tau)$. Since

$$\psi(\tau) = \int_{-\infty}^{+\infty} \phi(\tau, z) q(z) dz \quad (4)$$

then

$$\begin{aligned} I_0 &= \int_{-\infty}^{+\infty} \psi(\tau) f_1(\tau) d\tau = \\ &= \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \phi(\tau, z) f_1(\tau) q(z) d\tau dz \end{aligned} \quad (5)$$

Considering only the effect of grain size on dynamics and neglecting the difference of distribution of stopping time due to layer separation of different grain size, τ and z are then two independent random variables,

$$f(\tau|z) = f_1(\tau) \quad (6)$$

and Eq. (3) becomes

$$J_0 = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \phi(\tau, z) f_1(\tau) g(z) d\tau dz \quad (7)$$

From equations (5) and (7) it can be known that the method above for calculating the statistical mean value can be used only when the grain size does not affect the distribution of stopping time (e.g., no layer separation phenomena). From Eq. (3) we know that the accurate calculation of J_0 depends on the solution of $f_1(\tau, z)$.

(8)

From the properties of the problems, we consider:

1. As in report I, the processing has statistical property;
2. As in report I, the processing has random property, the no-later-effect property of Markoff process, and synchronism.
3. Different from report I, the conditions of action will be different for different grain size, but same for the same grain size assumptively. [Note: In this article, the variation of shape and weight of solid material in the processing is not considered. It is assumed that all the particles have same shape and same weight. The consideration of the variation of weight during the processing has been reported.]

The discharge probability $W(z)$ of the particle of the grain size $(z, z + dz)$ depends on the amount of particles with that grain size range in the system as well as the grain size. The former is expressed by $q_0(z)dz$ ($q_0(z)$ is the distribution density of grain size); while the latter is expressed by $W(z)$. The discharge probability is then expressed as $W(z)q_0(z)dz$.

The property of $W(z)$ can be expressed by the following two relations:

$$1, \quad \int_{-\infty}^{\infty} W(z)q_0(z)dz = 1 \quad (8)$$

This is normalization;

$$2, \quad W(z)q_0(z) = q(z) \quad [\text{See Note}] \quad (9)$$

That means the discharge probability density of different grain size particles should be expressed to be the total distribution density of grain size of material at the outlet. This is required by Glevenko's Law concerning large numbers of particles. [Note: Normally the

distribution of grain size of feeding material is the same as that of the discharge. The amount of the feeding is also the same as that of the discharge.)

$w(z)$ is the relative probability of discharge of different grain size particles as the other parameters are fixed.

The assumption of random motion of particles of each grain size determines the negatively exponential distribution of stopping time. However, the infinitesimal conversion probability density, $\lambda(z)$, varies with z . Then,

$$f(v|z) = \lambda(z) \exp[-\lambda(z)v] \quad (10)$$

and

$$\lambda(z) = \frac{q_1 W(z) q_0(z) dz}{v q_0(z) dz} = \frac{q_1}{v} W(z) = \frac{W(z)}{T_0} \quad (11)$$

where q_1 is the amount of solid fed per unit time; v the total amount of solid in the system; and T_0 the total mean stopping time of the solid. (We did not specify before whether the distribution of grain size is by weight or by number of particles, but here the grain size distribution should be by weight since q_1 and v are determined by weight. Thus, correspondingly, $w(z)$ is the relative probability of unit weight discharge as well as that of one particle discharge.)

From Eq. (11), it is known that $w(z)$ corrects the total mean stopping time, i.e., different grain size particles have different stopping times, $T(z)$, $T(z) = T_0 / W(z)$. Substituting Eq. (11) into Eq. (10) we get

$$f(v|z) = \frac{W(z)}{T_0} \exp\left[-\frac{W(z)v}{T_0}\right] \quad (12)$$

$w(z)$ is the resultant of the two opposite tendencies -- material mixing and layer separation by weight -- in the system. Therefore, it is affected by geometric condition and fluid dynamic conditions.

(D)

Bringing on Eq. (12) and Eq. (5), we get

$$I_2 = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \phi(v, z) \times \\ \times \frac{W(z)}{T_0} \exp\left[-\frac{W(z)v}{T_0}\right] q(z) v dz dv \quad (13)$$

$$I(s) = \int_0^\infty \phi(r, s) \frac{r^2}{r_0^3} \exp\left[-\frac{17(r/s)^2}{2}\right] dr \quad (14)$$

Drawing on Eq. (13), we get

$$I_0 = \int_0^\infty I(s) \phi(s) ds \quad (15)$$

During the solid chemical processing the external diffusion of the particles sometimes is not the control factor of the reaction rate (this was proved by other experiments), but the chemical reactions or the inner diffusion of the solid phase are the feature. Theories and experimental results published show that $J(z)$, for control of inner diffusion of the solid phase can be expressed as:

$$I(s) = \frac{1}{3} \frac{\theta(s)}{r(s)} - \frac{19}{20} \left[\frac{\theta(s)}{r(s)} \right]^2 + \\ + \frac{41}{4620} \left[\frac{\theta(s)}{r(s)} \right]^3 - 0.00145 \left[\frac{\theta(s)}{r(s)} \right]^4 + \dots$$

where $\theta(z)$ is the reaction time for complete conversion of particles of grain size z . $\theta(z) \propto z^2$. For control of chemical reaction, $J(z)$ can be expressed as

$$I(s) = \frac{1}{4} \frac{\theta(s)}{r(s)} - \frac{1}{20} \left[\frac{\theta(s)}{r(s)} \right]^2 + \\ + \frac{1}{120} \left[\frac{\theta(s)}{r(s)} \right]^3 - \frac{1}{440} \left[\frac{\theta(s)}{r(s)} \right]^4 + \dots$$

where $\theta(z) \propto z$. For these two control factors, if very high conversion is required, we must have $R(z) > \theta(z)$. Then take the first approximation and neglect the terms with higher powers. (For instance, when $J(z)$ is required to be 0.05, the error should be less than 5%.) Its general form is

$$J(z) = \frac{1}{k(z)R(z)} \quad (16)$$

where

$$k(z) = \frac{k_0}{z^2} \quad (17)$$

(Here we use $2m$ for convenience of calculation.)

The Eq. (15) becomes

$$J_0 = \int_{-\infty}^{\infty} \frac{W(z)}{k(z)T_0} q(z) dz. \quad (18)$$

From Eq. (8) and the normalization of $q(z)$, the following condition will be obtained

$$\int_{-\infty}^{\infty} \frac{q(z)}{W(z)} dz = 1 \quad (19)$$

In Eq. (18) J_0 is an entire function which is determined by $W(z)$ when $k(z)$, T_0 , and $q(z)$ are fixed. In practical cases, there should exist an optimum layer separation expressed by $W_{opt}(z)$ to make J_0 minimum, $(J_0)_{min}$, and to satisfy Eq. (19). In the present paper we use the Euler's variational method to solve this variation problem. To process a definite differential, divide the grain sizes of particles into n portions. Let

$$\left. \begin{aligned} q(z_i) \Delta z_i &= a_i; & W(z_i) &= W_i; \\ k(z_i) &= k_i; & T(z_i) &= T_i, \end{aligned} \right\} (1 \leq i \leq n)$$

$$J_1 = \frac{W_i}{k_i T_i} \quad (20)$$

$$J_0 = \sum_{i=1}^n \frac{a_i W_i}{k_i T_i} \quad (21)$$

([Note]: Actually, $q(z_i)$ should be $q(\xi_i)$, i.e., $z_i \leq \xi_i \leq z_i + \Delta z_i$. We take the mean value of the function. For convenience, the present article still uses $q(z_i)$. Same for $W(z_i)$, $k(z_i)$, and $T(z_i)$.)

The condition Eq. (19) can be written

$$\sum_{i=1}^n \frac{a_i}{W_i} = 1 \quad (22)$$

Now J_0 is no longer an entire function but a function of multiple variables. Using the Lagrange multipliers method to solve the conditional extreme of J_0 under the condition of equation (22), we get

$$(W_i)_{opt} = \sum_{i=1}^n a_i \sqrt{\frac{k_i}{T_i}} \quad (23)$$

Substitution of Eq. (17) yields

$$W_{opt}(z) = \frac{W_0}{\mu} \quad (24)$$

([Note]: W_0 is the mathematical expectation value. Same for others.)

At the optimum layer separation, drawing on Eq. (24) and Eq. (21) yields

$$(J_0)_{opt} = \sum_{i=1}^n \frac{c_i m_i^n}{\eta_i^n T_i^n} = \sum_{i=1}^n \frac{c_i T_i^n}{k_p T_0} = \frac{[m]_n^2}{k_p T_0} \quad (25)$$

$$(J_1)_{opt} = \frac{\sigma^n}{m^n} (J_0)_{opt} \quad (26)$$

When the process is controlled by inner diffusion of solid ($n = 1$),

$$\psi_{opt}(x) = \frac{\sigma x}{\delta} \quad (27)$$

$$(J_0)_{opt} = \frac{[m]_n^2}{k_p T_0} = (J_0)_{un} \quad (28)$$

$$(J_1)_{opt} = \frac{\sigma}{m} (J_0)_{opt} \quad (29)$$

$(J_0)_{un}$ in Eq. (28) is the unconversion rate of the homogeneous particles of grain size m under the same condition.

When the process is controlled by reaction ($n = 0.5$),

$$\psi_{opt}(x) = \frac{\sigma x^{0.5}}{\delta^{0.5}} \quad (30)$$

$$(J_0)_{opt} = \frac{[m]^{0.5}]^2}{k_p T_0} < J_{un} = \frac{m}{k_p T_0} \quad (31)$$

$$(J_0)_{opt} = \frac{\sigma^{0.5}}{m^{0.5}} (J_0)_{un} \quad (32)$$

Thus, we have this conclusions

1. A definite layer separation phenomenon is advantageous.

2. From Eq. (26) it can be known that at the optimum layer separation, $n = 1$, the conversion rate of the grain size with broad distribution is the same as that of even grain size (grain size is the mathematical expectation value of distribution, M_2). From Eq. (31), when $n = 0.5$, the grain size distribution can increase the conversion rate more than that of the material with even grain size. [See Note] Therefore, the grain size distribution is not a disadvantage without compensation. [Note] The intermediate condition is between these two conditions. For instance, if both reaction and inner diffusion of solid phase affect the process at the same time, then $0.5 < n < 1$.

Sometimes there exists a condition that the small particles are controlled by reaction and the large ones by inner diffusion of solid phase.)

3. From equations (29) and (32) it can be known that at the optimum layer separation, the particles of smaller size should have a higher mean conversion rate.

(E)

From the condition of Eq. (22), the general form of W_1 can be expressed as polynomial. The different power of p expresses the different degree of layer separation.

$$W_1 = \frac{m^2}{d} \quad (33)$$

Now,

$$I_0 = \sum_{i=1}^n \frac{a_i}{k_0 T_0} \frac{p^i}{100^i} = \frac{m^2 - p \cdot m^2}{k_0 T_0} \quad (34)$$

The two limits of layer separation are corresponding to $p = 0$ (no layer separation) and $p = 2$ (extreme layer separation). (Note: The small particles are mostly carried out by a gas stream. From the data of gas stream carrying, when z_1 is minimum, the speed constant of carrying is proportional inversely to z_1 of power 2.6 (the constant corresponding to the relative discharge probability in the present article), i.e., $W(z) \propto \frac{1}{z^{2.6}}$. The large particles are discharged by

overflow mostly. They are not related with z_1 too much. Industrial equipment always has small particle recovery. Thus, in general, p is not greater than 2, and its maximum does not exceed 2 too much. For simplicity, we discuss by supposing $p = 2$ as a limit.) The optimum layer separation is $p = m$. First we consider $m = 1$

$$1, p = 0, \quad (J_c)_{p=0} = \frac{m^2}{k_0 T_0} \quad (35)$$

$$2, p = m = 1, \quad (J_c)_{m=1} = \frac{[m^2]^2}{k_0 T_0} \quad (36)$$

$$3, p = 2, \quad (J_c)_{p=2} = \frac{m^2}{k_0 T_0} \quad (37)$$

Eq. (37) is identical to Eq. (35). When k_0, T_0 are the same, then

$$(J_c)_{p=2} = (J_c)_{p=0} > (J_c)_{min}$$

The ratio is

$$\left[\frac{(J_0)_{p=2}}{(J_0)_{min}} \right]_{T_0} = \frac{m^2}{[ms]^2} = 1 + \left(\frac{\sigma}{ms} \right)^2 \quad (38)$$

where σ is the square deviation.

Consider $m = 0.5$

$$1, p=0, (J_0)_{p=0} = \frac{m^2}{k_p T_0} \quad (39)$$

$$2, p=1, (J_0)_{p=1} = \frac{[ms^2]^2}{k_p T_0} \quad (40)$$

$$3, p=2, (J_0)_{p=2} = \frac{[ms^2] \cdot [ms^{-1}]}{k_p T_0} \quad (41)$$

Compare equations (39) and (41), from Holder inequality, we know

$$[ms^2] \cdot [ms^{-1}] > ms$$

Hence

$$(J_0)_{p=2} > (J_0)_{p=0} > (J_0)_{min}$$

The biggest ratio between the values of J_0 is taken from Eq. (39) and Eq. (40), and has a value

$$\left[\frac{(J_0)_{p=1}}{(J_0)_{min}} \right]_{T_0} = \frac{[ms^2] \cdot [ms^{-1}]}{[ms]^2} \quad (42)$$

Consequently, we can conclude:

1. The maximum deviation from the optimum layer separation phenomenon depends on the numerical characteristic of the distribution of the grain size of material.

2. Equations (38) and (42) can be used to determine the bad results caused by a certain distribution of grain size. Accordingly, we may improve them during design and operation.

3. When process speed is controlled by inner diffusion of solid phase, the result which is obtained by using the method of statistical average from Eq. (5) is safety. However, the result is uncertain when controlled by reaction.

The authors wish to thank Messrs. Li Chen-min (2621 2132 3046), Chu Feng-shen (2512 6646 3947), and Chuang I-shen (2369 0001 1344) for their valuable advices.

(P)

When other parameters (operation parameters, geometrical parameters, etc.) in a fluidization system are fixed, $W(z)$ is a definite function. By changing properly these parameters we can change $W(z)$ correspondingly to meet the requirement of the process. Such changes relate, for example, to the fluidization rate, the solid capacity of the system, the geometric shape and size of the system, the apparatus (e.g., cooling coils, etc.), and the efficiency of equipments of dust absorbers.

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DOUBLE ISOMORPHIE IN
CeNbTiO₆--YNbTiO₆ SERIES

[Following is a translation of an article by Chang P'ei-shan (1728, 1014, 0810) in the Chinese-language periodical K'o-hsueh T'ung-pao (Science Bulletin), No 12, Peiping, December 1952, pages 52-57.]

Dimorphie in mineralogy refers to minerals with identical chemical composition but different structures. Isomorphie refers to the phenomenon of mischkristalle between crystals of minerals with close chemical compositions but identical structures. In our study of rare earth-titanium-niobium salt minerals with ortho-rhombic AB₂X₆ structure, we discovered a phenomenon of complete isomorphie with dimorphie at the same time. We therefore suggest the name of double isomorphie for this phenomenon.

Ortho-rhombic AB₂X₆ rare earth-titanium-niobium salt minerals include euxenite, niobium-euxenite^(1,2), yttrium-cerium-euxenite⁽³⁾, yttrium-euxenite, polycrase, as well as high-temperature euxenite (hai-nsi-chin-k'uang), high-temperature polycrase (fuchsi-chin-k'uang).

Sinianite (chen-ton-kuang)⁽⁴⁾, and Tyndochite^(5,6).

That the crystal structures of euxenite and yttrium-euxenite are the same ($C_{2h}^{12} = P_{6mm}$) has already been shown by X-ray structural analysis^(7,8). Due to the pronounced difference in geo-chemical characteristics between the cerium element and the yttrium element, the mineral is euxenite ($CeNbTiO_6$), when it is rich in cerium, or yttrium-euxenite ($YNbTiO_6$), when it is rich in yttrium. In recent years, euxenite containing both cerium and yttrium has been discovered^(3,9). This has explained the existence of mischkristalle in the $CeNbTiO_6$ - $YNbTiO_6$ series. Moreover, X-ray spectrum analysis has shown the diadochie of cerium and yttrium in the composition of euxenite⁽¹⁰⁾.

As in the case of unlimited replacement (diadochie) between high-valence (keo-p'ei-wai) cerium and yttrium, the large-scale replacement between hexa-valence (liu-p'ei-wai) niobium and titanium in this series of minerals is also possible⁽¹⁾. Thus, the mineral composition diagram (Figure 1) has been made.

The principal chemical components of ortho-rhombic AB_2X_6 rare earth-titanium-niobium salt minerals are oxides of niobium, titanium, cerium, and yttrium (about 80% by weight). The diagram is made on the basis of the relative contents of these four major components.

In addition to minerals of the euxenite-yttrium-euxenite series, other minerals of the same group, high-temperature euxenite and high-temperature polycrase, have also been plotted on the diagram. It may be seen clearly from the diagram that the minerals with the same chemical

Composition as yttrium-euxenite is high-temperature euxenite (YNbTiO_6).²

However, it has been shown by both crystal geometric measurement and X-ray structural analysis^(7,11,12) that the two minerals are isomers.

In other words, the space-group of high-temperature euxenite is

$$C_{2h}^{14} = P_{\text{con}}.$$

The diagram also clearly shows that the mineral with composition close to that of high-temperature euxenite is high-temperature polycrase, the former being rich in niobium and the latter high in titanium. They differ only in the relative contents of niobium and titanium and not in crystal structure^(12,13).

The isomers of YNbTiO_6 are yttrium-euxenite and high-temperature euxenite. Besides euxenite, what are the other isomers of CaNbTiO_6 ?

Data of X-ray powder analysis (analyst: Wang Kuen-hsin) of euxenite, sinianite, high-temperature euxenite, and others, after heat treatment, are shown in Table I (Note). The powder pattern of euxenite remains the same after heat treatment. Sinianite and high-temperature euxenite, on the other hand, vary within euxenite and high-temperature euxenite phases depending on heating conditions. Earlier researchers^(14,15) classify sinianite under euxenite-group minerals. On the basis of chemical composition, sinianite may be considered as an uranium-rich variation of euxenite (namely, uranium-euxenite). (Notes: Through specific mineralogical studies, including total chemical analysis and physical property studies, these minerals were properly identified.)

2. Two types of powder pattern show up when euxenite, niobium-

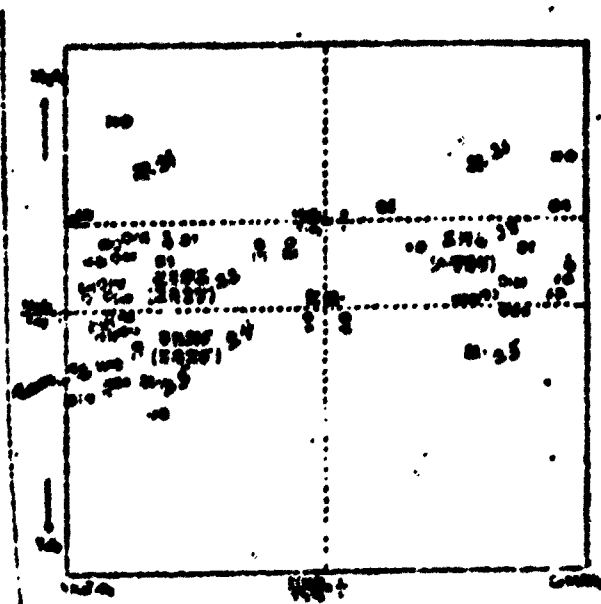


Figure 1. Relationship between the L major components in minerals of $CeNbTiO_6$ -- $YNbTiO_6$ series

Legendes

A. Dots indicate euxenite, niobium-euxenite, yttrium-cerium-euxenite, yttrium-euxenite, and polycrase.

- 1, 2, 3, 4 -- euxenite (Dana, 1914)
- 8, 9 -- yttrium-euxenite (Dana, 1914)
- 13, 14, 15, 17 -- polycrase (Dana, 1914)
- 7 -- yttrium-euxenite (Brögger, 1906)
- 11, 12 -- polycrase (Brögger, 1906)
- 5 -- euxenite (Sobolev and others, 1957)

Table 3. Two forms of,



Euxenite--yttrium- euxenite series	-sinianite--high- temp. euxenite series	Characteristic formula	$\text{Nb}_2\text{O}_5/\text{TiO}_2$
$d_{2h}^{16} = p_{\text{nm}}$ $a_0 = 5.0 \text{ \AA}$ $b_0 = 10.0 \text{ \AA}$ $c_0 = 7.0 \text{ \AA}$ $Z = 4$	$d_{2h}^{14} = p_{\text{cm}}$ $a_0 = 5.5 \text{ \AA}$ $b_0 = 14.0 \text{ \AA}$ $c_0 = 5.0 \text{ \AA}$ $Z = 4$		
niobium- euxenite	lyndochite (?)	CaTiNbO_6	2/1
euxenite	-sinianite	$(\text{Ca,TR})(\text{Nb,Ti})_2\text{O}_6$	1/1 - 2/1
titanium- euxenite (?)		CaNbTiO_6	1/1
Titanium-yttrium- euxenite (poly- cryst)	titanium-(high- temp. euxenite) (high-temp. poly-cryst)	YNbTiO_6	1/1
yttrium-euxenite	high-temp. euxenite	$(\text{Y,TR})(\text{Nb,Ti})_2\text{O}_6$	1/1 - 2/1
niobium-yttrium- euxenite (?)	niobium-(high- temp. euxenite) (?)	YTiNbO_6	2/1
yttrium-cerium- euxenite		$(\text{Ce,Y})\text{NbTiO}_6$	$\text{Ce}_2\text{O}_3/\text{Y}_2\text{O}_3$ 1/1

Table 1. Powder pattern of some AB_2X_6
rare earth-titanium-niobium salt minerals after heat treatments

Heating condition	Muffle furnace 550°C ± 30° 6-7 hours	Differential furnace (ch'a-Jo-Lu)(°C±20°) 500 600 700 800 900 1000						Muffle furnace 800°C ± 30° about 2 hours
euxenite	euxenite phase	← euxenite phase →						
niobium-euxenite	euxenite phase							
sinianite	high-temp. euxenite phase	← euxenite phase →					high-temp. euxenite phase	transitional phase of euxenite--high-temp. euxenite
high-temp. euxenite	high-temp. euxenite phase	← euxenite phase →						euxenite phase
high-temp. polycrase	high-temp. polycrase phase							

• Mineral samples taken uniformly and examined for purity under microscope.

• Pattern basically same as eucenite phase, differing slightly in minor details.

eucenite, sinianite, high-temperature eucenite, and high-temperature polycrase are heated at 550 C for 6-7 hours. Sinianite, high-temperature eucenite, and high-temperature polycrase show high-temperature eucenite phase, entirely different from eucenite and nicolow-eucenite. The X-ray data for sinianite also coincide with those of standard high-temperature polycrase (Table 2), showing that the crystal structure of sinianite is the same as that of high-temperature eucenite when heated under these conditions. Thus, we recommend the name γ -sinianite.

Results of powder analysis of γ -sinianite are listed in Table 2. The unit cell values of γ -sinianite are also shown in Table 2. These are calculated according to the standardized powder X-ray data of V. B. Alexandrov for high-temperature polycrase⁽¹³⁾, a_c from the d value of the 200 and 400 "lines"; b_0 from 060, 210, and 330; c_0 from 012, 030, and 004. To facilitate comparison, data of V. B. Alexandrov for high-temperature polycrase are also listed in Table 2.

It may also be seen from Figure 1 that the principal components of sinianite and eucenite are the same. There is, therefore, no question that eucenite and γ -sinianite are both isomers of CaSi_2O_6 .

X-ray data show that there are some high-temperature eucenite which contains considerable amount of series, showing that replacement

Table 2. β -intensity (1) and d -spacing (2) of crystallites. Analyzed: polyacetylene
 photographic conditions: $\lambda = 57.3$ nm, voltage 35 kV, $i = 20$ mA,
 exposure 1 hour
 high-temperature polymers (1,100°C)
 $a_0 = 5.55$; $b_0 = 14.62$; $c_0 = 5.13$ Å

According to Stepanov & Tsvetkov, 1955

β -intensity $a = 5.37$; $b = 14.70$
 $c = 5.10$ Å

hkl	Z	d calculated, Å	Z	c measured, Å
111	2	3.67	3	3.66
121	1	3.37	6	3.28(130.8)*
140	10	2.99	10	2.99
200	2	2.78	3	2.768
220	2	2.59	3	2.58
042	2	2.59	3	2.58
221	2	2.45		
022	2	2.45		
060	2	2.44	3	2.435
112	1	2.32	2	2.305
032			2	2.30
240	2	2.310		
201	2	2.187		
131	2	2.113	2	2.115
211			1	2.015
141	1	1.977		
022	1	1.941		
222	2	1.934	3	1.90
222	4	1.815	9	1.825
062	3	1.776	4	1.775
350	4	1.729	3	1.734
113	3	1.641	3	1.645
124	1	1.611	1	1.614
352			1	1.596
113	2	1.564	2	1.567
			2	1.553
252	4	1.456	6	1.492
213	1	1.450	1	1.462
223	2	1.440	3	1.442
213	1	1.406		
400	1	1.387	0.5	1.394
420	1	1.343	0.5	1.37
411	2	1.335	1	1.34
			0.5	1.316**
004	1	1.297	1	1.297
			1	1.285**
313	2	1.223	2	1.225
460	1	1.206		
432	1	1.186	1	1.188
451	1	1.174	3	1.179
153	3	1.153	3	1.1537
144	1	1.121		
110.3	1	1.117		
460	1	1.103	1	1.1045
291	1	1.089		
431	2	1.081	2	1.085
433	1	1.052	2	1.0593
244	1	1.053	2	1.059
			3	1.025
115	2	1.017	1	1.019
355	1	0.999	1	0.9973
			2	0.996
195	2	0.963		
195	2	0.941		
172	2	0.917		

* line already observed
 ** measured line width

between cerium and yttrium in the mineral is possible. On the other hand, the existence of yttrium in sinianite also indicates that the formation of mischkrystalle between α -sinianite ($\text{Ce}_{0.5}\text{Y}_{0.5}\text{TiO}_6$) and high-temperature euxenite (YNbTiO_6) is similarly possible.

Consequently, it is very clear that two types of compounds with entirely different structures can be formed in the $\text{Ce}_{0.5}\text{Y}_{0.5}\text{TiO}_6$ -- YNbTiO_6 series, one being euxenite--yttrium-euxenite minerals and the other α -sinianite--high-temperature euxenite minerals. Each of the two series of minerals has its own intermediary transitional variations and these minerals can all form isomorphous mischkrystalle or mixed crystals of same structures (Figure 1 and Table 3).

Under high temperatures, yttrium-euxenite and polycrase respectively transform into high-temperature euxenite⁽⁷⁾ and high-temperature polycrase⁽¹³⁾. On the other hand, sinianite, upon heat treatment, transforms into α -sinianite with high-temperature euxenite phase (Table 1) while high-temperature euxenite shows the euxenite phase (Table 1). Thus, there is reason to believe that under certain conditions the appearance of euxenite transforming into α -euxenite of high-temperature euxenite phase is a possibility, and in the future we may find in nature euxenite with high-temperature euxenite structure.

The entire picture becomes even clearer if we divide each of the two series of minerals into a number of chemical variations according to the ratio of measured percentage contents of niobium oxide and titanium oxide (Table 3). We can see from the table that aside from

Table 3. Two forms of,



Euxenite--yttrium- euxenite series	-sinianite--high- temp. euxenite series	Characteristic formula	$\text{Nb}_2\text{O}_5/\text{TiO}_2$
$d_{2h}^{16} = p_{\text{bnm}}$ $a_0 = 5.0 + \overset{\circ}{\text{A}}$ $b_0 = 10.0 + \overset{\circ}{\text{A}}$ $c_0 = 7.0 + \overset{\circ}{\text{A}}$ $Z = 4$	$d_{2h}^{16} = p_{\text{can}}$ $a_0 = 5.5 + \overset{\circ}{\text{A}}$ $b_0 = 14.0 + \overset{\circ}{\text{A}}$ $c_0 = 5.0 + \overset{\circ}{\text{A}}$ $Z = 4$		
niobium- euxenite	lyndochite (?)	CaTiNbO_6	2/1
euxenite	-sinianite	$(\text{Ca,TR})(\text{Nb,Ti})_2\text{O}_6$	1/1 - 2/1
titanium- euxenite (?)		CaNbTiO_6	1/1
Titanium-yttrium- euxenite (poly- cryst)	titanium-(high- temp. euxenite) (high-temp. poly-cryst)	YNbTiO_6	1/1
yttrium-euxenite	high-temp. euxenite	$(\text{Y,TR})(\text{Nb,Ti})_2\text{O}_6$	1/1 - 2/1
niobium-yttrium- euxenite (?)	niobium-(high- temp. euxenite) (?)	YTiNbO_6	2/1
yttrium-cerium- euxenite		$(\text{Ce,Y})\text{NbTiO}_6$	$\text{Ce}_2\text{O}_3/\text{Y}_2\text{O}_3$ 1/1

Titanium-euxenite and niobium-yttrium-euxenite of the euxenite-yttrium-euxenite series minerals yet to be discovered in nature include those equivalent to -sinianite⁽¹⁾. On the other hand, the structure of lyndochite^(5,6) deserves a more intensive study.

Based on the theory of isomorphic replacement, the appearance of high-tantalum, high-thorium, high-uranium, and high-iron variations of the above two series of minerals would be a possibility.

The question of the type of geological conditions under which specific minerals in the two series are formed is a subject that deserves further studies.

The author's appreciation goes to Professor Ho Tso-lin for his direction of this work and to Mr. Kuo Chieng-chi for reviewing the manuscript and giving valuable suggestions.

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CS: 2550-6

1962 TECHNOLOGICAL CONFERENCE OF THE
PHARMACOLOGY SOCIETY OF CHINA

Following is a translation of a report by Shih Kung (4258, 0361) in the Chinese-language periodical K'ueh-sueh T'ung-pao (Science Bulletin), No 12, Peiping, December 1962, pages 50-60.7

A national technological conference of the Pharmacology Society of China was held in Peiping between 27 October and 2 November 1962. The important problem discussed during the conference was the search for new drugs. Altogether 14 reports were presented.

Huang Ming-lung (7806, 7686, 7893) presented a report on the "Changes in Ovarian Hormone Structure" describing how changes in chemical structure can greatly increase the clinical effectiveness, reduce side effects, as well as the special ability of changing the effect. It also explains the methods of adding such radical groups as 16 -Hydroxy-9 -F-1-Dehydro-"k'o-ti-tso" and 16 -Methyl-9 -F-1-Dehydro-"k'o-ti-tso." Lei Hsing-hen (7191, 5281, 5060) presented a report on the "Present and Future of Synthetic Drugs for Halothanesis"

Introducing China's achievements in synthetic drugs against kala-azar, ascariasis, schistosomiasis, and hookworm disease. Fu Feng-yung (0265, 0023, 3057) introduced the research work done in recent years on such major plant chemical constituents as alkaloids, ovarian compounds, glucosides, and menthene and presented his viewpoints and suggestions on the future development of botanic chemistry and on the search for new drugs.

T'ien Ping-chien (6223, 3521, 2638) presented a report on the "Planting of Pharmaceutical Plants" introducing mainly the conditions of planting cultivation in China and the major tasks involved in this work. The author feels that three questions should be considered prior to a decision to proceed with plantings: (1) The future of the medicinal plant itself; (2) the biological and ecological characteristics of the medicinal plant; and (3) the overall natural environments of the original location where the plant is growing and the area where it is to be planted. During planting, the seeds or seedlings should be examined for diseases and suitable growing requirements must be provided.

Lou Chih-t'ien (2869, 0057, 1476) presented a report on the search for new medicinal plants. He believes that the search for new medicinal plants should be based on the people's experience of using medicine and on plant relationship.

Hsu Ju-cheng (6079, 3067, 2773) and T'iu Kuei-t'u (3205, 0948, 0960) submitted a report on new medicines, with emphasis on organic

chemical drugs and quality control. In manufacturing and that the standard specifications of drugs should primarily guarantee the safety and effectiveness when consumed. Consideration should also be given to domestic production conditions and costs.

Wang Kuo-fen (3076, 3948, 5353) and Cheng Nan-sen (1726, 2809, 2773) introduced some practical problems in the bed-side application of new drugs. For instance, not few of the new drugs adopted for bed-side application had shown indeterminate results or even negative results. New toxicity, side effects, and over-sensitive reactions were often found. Problems even existed with some old drugs which had been adopted for some time. Thus, they feel that careful laboratory study should be carried out on new drugs both before and after their adoption for bed-side application and this is one of the basis of the accurate evaluation of new drugs. At the same time, the manufacture, structure, and dispensation of new drugs should be studied in order that they may be correctly applied.

Ku Hsueh-ch'iu (7357, 1331, 3941) described the trends in drug research and introduced the achievements in this field during the past 10 years in China as well as overseas. He also made some recommendations on China's research work in the future.

Liu Kuo-chieh (0491, 0942, 0267) presented a report on prescription of drugs and the problem of prescription cans. He contends that to insure or increase the stability and homogeneity of the effective component of the drug, thereby guaranteeing its safety and effec-

Effectiveness, is the major goal of research in this area.

Shan Chia-hsiang (3083, 1367, 1382) submitted a report on the study of new drugs, the research in pharmaceutical production, and on pharmaceutical chemistry. He described in detail the entire history of research for new drugs, the responsibilities of pharmacological chemists, as well as the complicated problems of biological experiments and pharmaceutical chemistry in the study for new drugs. He believes that the organization for the study of new drugs may be centered on diseases, in other words, following the line of "searching for new drugs against specific diseases;" It may also be based on [chemical] compounds, starting along the line of their structural changes and finding new drugs through the screening of many inter-related pharmaceutical theories.

Ku Nan-i (7357, 3352, 7328) presented a report on the question, "What is the basis of the work of searching for new drugs?" He emphasized that the work of searching for new drugs must go through the three stages of laboratory study, bed-side study, and production study. The work of production study has often been neglected. As a result, accidents have continued to take place in production and in bed-side application. He also pointed out that in the work of production study attention should be given to checking the quality of trial manufacture in connection with safety and effectiveness, such as checking the major drug and its content, testing of impurities, effect of the drug in different forms (possibly referring to pills, liquid, and

for injectibles⁷, as well as bed-side testing, etc.

Hsu Yu-chun (1776, 3760, 0371) reported on the direction of bio-assay work, pointing out that difference in quality between a standard product and a sample product could lead to a series of problems in the method of bio-assay and in bed-side application. He also described the developments in laboratory methods for sample treatment, animal selection, target observation, and bio-statistics.

Chi Ju-yun (1472, 5067, 6663) reported on the direction of development of pharmaceutical chemistry and discussed the question of searching for new drugs based on the principle of uniting the theories of molecular structure and electron distribution density with the theory of "biological code transmission" (sheng-wu shou-t'i).

Hsu Kuo-chun (1776, 0948, 6874) presented a report, entitled "On the Science of Drug Materials and Its Tasks." He contended that "science of raw drugs" ("sheng-yao-hsueh") should be changed to "science of drug materials" ("yao-ts'ai-hsueh") and stated that the basic responsibilities of yao-ts'ai-hsueh should include the production of drug materials, their identification, study of chemical composition, manufacture, their effects, resources, and identification of herbs.

The conference received altogether 563 papers related to the science of drug theories, science of raw drugs, botanical chemistry, chemistry of drug synthesis, drug analysis, and pharmacy. These papers covered a much wider field than in the past and the discussions were

more intensive. For instance, in the study of composition of pharmaceutical plants, the amount of work on chemical structures increased. Moreover, on certain subjects, discussions on entire series of research work appeared (such as the study of the chemistry and drug theory of *Thalictrum officinale*, Juss. as a heart stimulant and the investigation of resources, testing of contents, and study of production technology of various (?) raw material plants).

Papers on synthetic drugs covered not only the study of drugs for tumors (chung-llu) and illnesses of the cardiac blood vessels but also drugs of wider applications such as drugs for the elimination of worms and drugs against parasites. There were also studies on new methods of production and testing.

Among papers on drug theories, the study of plant drugs occupied a larger percentage; in the method of research, the application of some modern techniques was covered. In the study of drug forms, emphasis was placed on actual bed-side application. In this connection, theoretical studies also had its beginning.

During the conference, the question of direction to be followed in the search for new drugs was discussed. In synthetic drugs, the representatives expressed their opinions on the question of what types of drugs should be given priority in research. They felt that emphasis should be given to preventive drugs and to drugs dealing with serious illnesses. On one hand, studies should be made on drugs that deal with more complicated illnesses, such as tumors and illnesses connected with

The blood vessel system of the heart and with the nervous system. On the other hand, neither should we neglect the studies on preventive drugs dealing with parasitic diseases which seriously affect industrial and agricultural production and with widespread illnesses. Some representatives also pointed out the importance of production studies on known raw drugs, of searching for new and more economical methods of synthesis, and of improving technical standards of production.

In the search for new drugs from pharmaceutical plants, the direction is the same as in the case of synthetic drugs. However, emphasis should be given to diseases which can not be satisfactorily solved by synthetic drugs. In cultivation studies, the major tasks are to raise the yield and quality of drug materials and to lower production costs. In the last few years, many planting farms have been established and some of these have not been successful. The reason for the failure has been primarily the over-emphasis on pharmaceutical plants from outside areas and the lack of attention on local plants. This situation must be remedied.

During the discussion of giving support to agriculture, it was proposed by some representatives that not only must we look for good new drugs to protect the rural labor forces and effectively support agriculture efforts should also be made to increase the amount and types of drugs against the common diseases in the rural areas and to increase veterinary drugs and drugs for the elimination of the four horses. Drug for the rural areas should be prepared as such in their finished

form as possible. In the case of prescriptions and dispensation, the following requirements should be met: (1) effectiveness in treatment, (2) stability, (3) low in cost, and (4) packing to meet rural needs. In addition, protective type drugs for paddy field work should be studied.

Regarding the road to follow in the study of synthesis of new drugs, some representatives were of the opinion that for the time being we should not leave the "experimental form" of method. The selective work of a large number of compounds is still of primary importance, which means the synthesis of new and possibly effective compounds, using as foundation chemical structures with specific biological effects and based on the principle of "putting together" effective structures or radicals. Some representatives pointed out that we should study those bio-chemical elements with pharmacological effects and proceed a step further to develop theories dealing with relationships between structure (including structural forms and electronic distribution) and effect as the direction of our search for new drugs. These two proposals are not considered as contradictory to each other.

Methods of studying new plant drugs are many. Clues could be found from traditional medicines, popular drugs, traditional prescriptions, popular habits (including the medical experiences of minority nationalities), and domestic and foreign literatures. Our target for research could also be based on plant affiliations of known drugs. Through these methods, a number of plant resources have been found in

Recent years, including the stems of domestically produced *Rhaphanus* *Sativus*, L. ("lo-fu-mu") as a high blood pressure depressant, *Strychnos* *nux vomica*, L. as a stimulant for the central nervous system, the bark of *Rhamnus japonicus*, Maxim. var. *genuina*, Maxim. as a laxative, and others. Some proposed that the selection of our target for research may be based on the traditional medicine theories regarding the causes of diseases.

In the area of pharmaceutical science, the representatives unanimously agreed that its goal and responsibility lie in the preparation and study of effective drugs which meet bed-side requirements. In the work of research, it is necessary to first solve the problem of what drug materials can be combined and what can not and the question of the stability of drugs. It was also recognized that the road of development lies in the utilization of the various basic sciences, such as physics, chemistry, chemical mechanics, colloidal chemistry, fluid mechanics, and various biological sciences. The theories of these sciences should be the basis to improve the research level of China's pharmaceutical science (yao-chi-ksueh).

In order to guarantee the safety and effectiveness of new drugs, suitable standards and regulations must be established. Some representatives believe that prior to production and bed-side application of new drugs, scientific studies should be carried out in order to establish these standards and regulations, these studies to include the physical and chemical characteristics of the new drug, the drug theory,

(the theory of its function) and toxicity, the study of possible bedside effects, study of factors which affect quality of production, study of impurities and their toxicity, study of the stability of new drugs and of their preparations, and the study of the methods of examination of new drugs. All this work should be included within the field of production study of new drugs and requires the concerted efforts of various organizations concerned. Various quality studies should be continued even after bedside application, thus maintaining a long term examination to insure the safety and effectiveness of a new drug.

In plant drugs, the question of standard specifications of traditional drug materials was also seriously discussed. That this was a complicated problem was recognized by all. It should be determined jointly on the basis of the experience of traditional pharmacists and modern scientific achievements. Studies should be made with forces of local areas as the foundation and with the cooperation of national research units. The authenticity of traditional drugs and their standards of purity should be clearly defined, while methods of determination should be speedy and accurate.

During the conference, opinions were exchanged between workers dealing in drug theories and those dealing with drug chemistry and botanical chemistry and their mutual understanding was increased. It was recognized that for better cooperation, mutual exchange of scientific knowledge was necessary. The best approach would be for those

Meeting in drug theories and the chemists to jointly determine the subjects for research and to proceed and jointly plan [chemical] compounds on the basis of common understanding. Thus, there would be a common interest toward any research subject, making cooperation easier. In the field of drug preparations, cooperative studies between pharmacies and hospital units should be strengthened. In addition, cooperation between various units and various departments should be properly implemented.

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CONFERENCE ON
CHEMICAL FIBRE TECHNOLOGY

Following is a translation of a report by Chang Chen-ya
(1725, 1014, 0063) and Wang Yu-huai (3769, 2589, 2849)
in the Chinese-language periodical K'g-hsueh T'ung-pao
(Science Bulletin), No 12, Peiping, December 1962, pages
60-61.7

In order to discuss the direction of development of China's
chemical fibre industry and to exchange ideas on problems dealing with
scientific research and technology, the Society of Chemistry and Che-
mical Engineering of China and the Society of Chinese Textile Engi-
neering jointly called in Shanghai a conference on chemical fibre
technology between 16 and 24 October 1962.

During the conference, 27 papers dealing with artificial fibres
and synthetic fibres were read and discussed. These papers dealt with
raw materials, quality of finished products, technology, equipment, and
the structure and properties of fibres. One section consisted of sum-
maries of production experiences or laboratory reports on intermediary

Type of production; the other part of the reports covered scientific research work. Some of them dealt with theoretical problems in production; others consisted of the checking of results of theoretical studies through production, showing the spirit of coordination between theory and practice and indicating a more systematic laboratory research work by various research and production units in recent years.

In the field of artificial fibres, extensive discussions were carried out on the development and utilization of their principal raw materials, with special emphasis on the selection of raw material pulp. It was generally recognized that within a definite period of time the major emphasis should be placed on the production of artificial fibre using quality wood pulp. Moreover, extensive resources investigation, cultivation, and development of different types of plant cellulose which can be used for artificial fibre production should be carried out on a national scale. These would include various types of fast-growing trees, ma-wi-sung, Larix la-golepis, Gord., butrus, as well as wheat stalks. Resources with a steady supply and for which technology is better developed (such as bagasse) should be studied and utilized according to local conditions.

The question of the reaction of the pulp was studied intensively during the conference. Some comrades made relatively detailed analyses on such factors as chemical composition and structure which affect the reaction of the pulp. Others presented their own views on the properties of reaction of various types of pulp, such as "small-leaved"

cinnamum camphor and sugar cane, based on their own research work and production experiences, which resulted in enthusiastic discussions. Quite a few comrades felt that a number of worthwhile studies remained in the methods of determining the properties of reactions; the choice of these methods should be determined by the overall conditions of the different types of pulp; one single formula and a single method should not be followed for all types of pulp. For example, coefficients of "obstruction" determined by traditional method coincide fairly closely with the filtering property of the pulp. However, it should be noted that the coefficient of "obstruction" during the initial stages of filtration is not a constant; the formula used in calculating the coefficient is only suitable for a normal solution. Consequently, for pulp with a large difference of degree of coagulation (chu-no-tu), an alkali cellulose must first be made and it should then be aged to close to the same degree of coagulation.

Regarding the question of quality of artificial fibre, intensive discussions were carried out during the conference on the poor color quality of artificial silk, especially the cause of producing silky colored silk. It was generally recognized that this was due to uneven technological conditions. Some people held the opinion that the appearance of silky silk is connected with such factors as post-treatment, uneven degree of "ripeness" of the solution, poor reacting capacity of the cotton pulp, and the conditions during drying. Thus, it is essential to adopt logical technological procedures, strictly control

Technological conditions, and improve machinery and equipment. Efforts should be exerted simultaneously on all these three areas to improve the quality of artificial fibres.

Discussion was also carried out on another key question in the technology of colloids - huang-suan-hua [literally, yellow acidifying; possibly connected with a process which has something to do with xanthate]. Regarding the current practice of "adding alkali" to improve the filtration ability of the solution, some believe that because of the additional action on the alkali cellulose, the homogeneity of huang-suan-hua is improved. Others believe that mainly because of the creation of the condition of solution and huang-suan-hua at the same time the diffusion rate of carbon disulfide into the cellulose is accelerated and the huang-suan-hua reaction becomes even more homogeneous.

In addition, varying amounts of discussions were also made on the relationship between the hsi-t'ei structure of fibres and their properties, on various types of machinery and equipment in the manufacture of artificial fibres, and the rationality of the various lines of production technology.

In synthetic fibres, the synthesis of Nylon (ni-lung) 66 was discussed. Preliminary studies were also made on the possibility of improving the heat stability of fibres through the adoption of ch'ieh-chih pien-hsing [literally, connecting branches, changing properties].

The comrades also expressed their views on the cross sectional form (hsing-t'ai) and structure of a fibre which affect its properties.

For example, some explained the difference in dye absorption by the angle of the cross sectional "form." Others believed that the difference was due to the difference in the size of voids produced in the "crystal area" (chin-ch'U). Others suggested that difference was created by both physical and chemical factors; thus, in considering the factors of "form" and structure, attention should also be given to the effect of the base property of the upper part of the large molecule.

Views were also exchanged between the representatives on the technological flow sheet in the manufacture "wei-ni-lung" fibre. Finally, certain theoretical questions in high molecule solution silk manufacture were also discussed.

It was unanimously agreed that together with the development of natural fibres the chemical fibre industry must also be rapidly developed. The current emphasis should be the development of artificial fibres. At the same time and depending on conditions, development should be carried out on synthetic fibres where better requirements exist.

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THE THIRD REPRESENTATIVES CONFERENCE
AND 1962 ANNUAL MEETING OF THE CIVIL
ENGINEERING SOCIETY OF CHINA

Following is a translation of a report by Huang Shu-pang
(7306, 2785, 6721) in the Chinese-language periodical K'uo-
hsueh T'ung-pao (Science Bulletin), No 12, Peiping, Decem-
ber 1962, pages 61-62.7

The Third Representatives Conference and the 1962 Annual Meeting
of the Civil Engineering Society of China were called in Peiping be-
tween 30 August and 7 September 1962.

The principal agenda of this conference consisted of the summary
of the working experiences of the Society since the second conference
and the discussion of the future tasks of the Society; amending the
regulations of the Society and the reelection of its managers; and tech-
nological discussions focusing on the question of degree of structural
safety in order to further the Party's policy of science development
through the "simultaneous blooming of hundred flowers and the struggle
for superiority by hundred parties."

Through conscientious selection by the Society in all parts of China, nearly 200 technical papers were received at the conference. An exhibition of engineering structures from both within the country and abroad was also held during the conference period.

The discussion on the degree of structural safety was the focal point of technological activity of the annual meeting. During the reporting session on this special topic, some comrades presented a number of major problems on structural safety from the construction point of view. Others introduced current methods used abroad in dealing with structural safety of reinforced concrete. Still others presented their viewpoints and suggestions on the same subject as it is encountered in practice in China.

The degree of structural safety is not only a question of technical theory, it is also a question of technical policy. By accurately determining the degree of structural safety, not only can we fully develop the potentials of materials and structure but we can also guarantee that a structure is economically logical and it is strong and safe. It was the consensus that the current design of China's building structures based on limiting conditions and using three coefficients was more advanced than past practice based on the breaking stage and using a single safety coefficient; the physical concepts became more clearly defined and it was easy to find a rule to be followed. Moreover, calling the three coefficients (coefficient of overloading, coefficient of nonuniformity, and coefficient of work condition) in the

Limiting condition design load coefficient, coefficient of material strength, and coefficient of work condition was believed to be more suitable. Views differed, however, on how to determine these three coefficients. Some believed that in order for a structure to have a greater safety reserve, larger coefficients should be used. Most of the comrades, however, believed that the magnitude of the coefficients should be based on actual conditions, and each situation should be dealt with separately. Since the coefficient of work condition covers various factors, it becomes more complicated. It should be more carefully determined on the basis of various engineering conditions and the location of sub-structures. On the other hand, certain allowances must also be provided. Although its determination is based on specific principles, the designer should be given some discretion depending on the time and the local conditions.

There were many papers on construction engineering and they covered a wide variety of subjects. Among them, Comrade Wang Kuang-yuen's paper on the "Logical Method of Calculating Kinetic and Static Forces of Single-story Industrial Buildings" caused considerable interest among participating representatives. The author points out in his paper that there is a basic difference between the forces sustained by the truss in space for possibly - forces sustained by the spaces in the truss of a single-story plant structure and those sustained by a "free" truss. The displacement of the chord beam in the truss of a single-story plant building is far smaller than that of a "free" truss and under load conditions.

It shows a shearing deformity, entirely different from the deformity shown by a "free" truss. As a result of many tests, the author believes that in calculations [the structure] may be treated as Wen-k'ueh's hypothetical elastic foundation beam; the equation(s) evolved is extremely simple and the results obtained are very close to actual practice.

Professor Wu Liu-sheng (0702, 2692, 3932) presented a report on "Theories of Calculating Strength of Reinforced Concrete Beams under Combined Effects of Torsional Moment and Shearing Force." In his paper, the author pointed out that there was a great deal to be desired in the current method of calculation for reinforcements in the transverse direction, the principal defect being that the effects of shearing resistance while resisting torsion was not taken into consideration. He suggested that the calculation should be based on Mohr's theory of strength; checking of the results with some experimental data from abroad showed that the suggested method was logical. This report resulted in enthusiastic discussions by those present at the conference.

Courace Ch'en Ju-hui (7115, 0320, 1520) presented a report, entitled "General Discussion on the Limiting (chi-hsian) Equilibrium Theory of Reinforced Concrete Thin Shell Structures." It was the contention of some representatives that in structural calculations such problems as relating to temperature stress, pillar subsidence, kinetic calculations, as well as stability and gradual deformity could not yet be solved by the limiting equilibrium method.

In coordination with papers presented at the conference, enthu-

Elastic discussions also developed on the question of structural shapes of industrial buildings and on the subject of the well system.

In the special sessions on railway, two reports on the subject of bridges by comrades Tsou Hung-jen (6760, 7703, 0028) and Ch'eng C'ing-tuo (1453, 1987, 0049) were presented. These were entitled, respectively, "Large Span, Prefabricated Reinforced Concrete Arch Design" and "The Experimental Study on Thin Plate Beams of Two Direction Prestressed Reinforced Concrete." In addition, discussions were carried out on a number of problems in the use of the limiting condition method of calculation in the design of China's railway bridges. Reports in this field received considerable interest and it was the unanimous belief that this is a new development in China's railway bridge techniques. Many railways in China are constructed in mountainous areas, and the adoption of some large span, top or middle supporting reinforced concrete arch bridges, coordinated with topographic conditions, is a logical choice. On bridges of ordinary spans, everyone agreed that material savings and weight reduction (10%) could be achieved through the use of two direction prestressed thin beams instead of single direction prestressed beams; technologically and economically, the former is decidedly superior and deserves emphasis, study, and further promotion.

In his paper, "Study of Concrete Rail Ties and Accessories," Comrade Yao Ming-ch'ü (1202, 2494, 0243) pointed out that the method of designing concrete rail ties according to "shu-ll" [possibly refer-

Finding to mathematics and physics/ statistical theories, which takes into consideration the repeated loads sustained during the entire period the ties are in use, is a more rational way of selection. This method coincides with actual experimental results and is, therefore, better in reliability and safety. According to investigations on the conditions of rail tie use, the author believes that "Hsien-152" model prestressed steel and concrete rail ties are more satisfactory and may be used as an important basis in the future for the selection of cross sectional strength of rail ties. On the question of accessories, the author believes that the "sulfur anchoring type" is superior.

It was unanimously agreed that the use of concrete rail ties on railway lines is a direction of future development. However, some problems require further studies and improvement, such as the excessive weight of concrete ties, the requirement of a wider road bed, and accessories.

During the special session on communication, four papers on the design and construction of stone arch bridges were read and discussed. There have been important developments in recent years on stone arch bridges, with considerable experiences accumulated on the selection of the shapes of bridges, designing theories and methods of calculation, and construction techniques. It was believed that China's highway bridges should be of many types and many shapes, the selection of which should be based on overall conditions, availability of local materials, the needs of local areas, and other favorable conditions. The construction

Design of bridges and culverts on rural roads should be based on real characteristics, with consideration being given to overflow bridges, "water access" road surfaces, or brick culverts. Regarding large span bridges and bridges to be built on soft foundations, a wide comparison of many methods should be made, thereby arriving at the most logical structural design both technically and economically. Further, in areas where the necessary requirements exist, prefabricated reinforced concrete structures and prestressed reinforced concrete structures should be developed in order to save material and labor and to speed up the rate of construction.

During the special session on municipal engineering, discussions were carried out, in coordination with papers presented at the conference, on the basis of three focal questions: (1) the design of prestressed and non-prestressed reinforced concrete water pipes and the standards for pressure tests; (2) the effect of longitudinal prestress and the standard for its calculation; and (3) the question of jointing of reinforced concrete water pipes and foundation preparation. Through these discussions, different viewpoints were exchanged, a number of concepts were defined, and some uniform understanding was initially achieved. However, a number of more complicated problems require continued accumulation of data and further studies.

Finally, a committee for the Society was reelected and Comrade Hao I-sheng (5403, 0110, 2573) was reelected as chairman.

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AN OUTLINE OF RAPIDLY DEVELOPED QUANTUM ELECTRONICS*

[Following is a translation of an article by Huang Wu-han (7305 2976 3352) and Pan Kuo-chien (5402 2654 0255) in the Chinese-language periodical, K'o-hsueh T'ung-pao (Science Bulletin), Peking, No. 12, December, 1952, pages 1-25.]

Quantum Electronics is a new field in physics. Its contents are expanding widely and we can hardly give it a complete definition. By and large, quantum electronics is a new science which deals with the research and the applications of resonance phenomena of interactions between electromagnetic waves (radiation), including radio-frequency radio waves, microwaves, infrared, and visible light, and microscopic systems (molecules, atoms, and electrons inside ions) to build corresponding quantum instruments. It is established on optical spectroscopy, r-f wave and microwave spectroscopy, and radio electronics, and is related closely to the quantum processes of atoms and molecules. Therefore, it is also called quantum radio physics, i.e., a combination of both quantum physics and radio technique.

Early in 1933 when they began to study the spectra of gases, scientists discovered that there occurred absorption phenomena (Phys. Rev. 15 [1934] 234), at the 1.25 cm wave length of helium. This gave the conditions for later gaseous quantum oscillators and amplifiers. In 1937, Rabi suggested a method to measure the distance between nuclei (1). Since the Russian E. K. Zavoiskii discovered (2) the spin paramagnetic resonance of electrons in 1944, a new branch of experimental physics, microwave spectroscopy, has been established. In 1951-1952, H. G. Basov, A. M. Prokhorov, and C. H. Townes pointed out the possibility in principle to use quantum system to produce and amplify electromagnetic waves (3, 4). In 1954-1955, the above two Russians proposed a working principle of three-energy-level quantum amplification. Both groups mentioned above built the first quantum oscillators-helium molecule beam oscillators almost at the same time. In August, 1955, J. P. Gordon, E. J. Zeiger, C. H. Townes, and etc. published papers to introduce a term "maser" (5a, b)

* This paper was read at the Radio Electronics Meeting sponsored by the Chinese Electronics Society.

(Microwave Amplification by Stimulated Emission of Radiation) to represent microwave amplified by stimulated emission, i.e., microwave quantum amplification. In 1956, N. Bloembergen calculated in detail the working conditions of the three-energy-level solid state quantum amplifier and predicted that it would have a very low noise level. This uses the bound electrons of materials in addition to classical electronics using free electrons. This is a new development which is growing very rapidly and it will gradually have its practical uses. In other countries new principles are used to extend the wave range and to increase the sensitivity and stability of equipment. From the point of view on quantum electronic techniques, due to the utilization of induced transitions, two basic problems in radio electronics which were not solved satisfactorily in the past can be solved: ultra-low-noise amplification and very high stability of frequency. The former can be used in radio pilot locating, radio-astronomy, cosmic telegraph, etc., and the latter can be used in Doppler pilot, space pilot, code telegraph, missile orbit parameter measurement and precise control of launching time. In 1958, N. G. Basov, A. M. Prokhorov, H. L. Schawlow, and C. H. Townes (52) proposed independently the possibility of using quantum amplification on waves from millimeter, infrared, to visible lights. The light quantum amplifier built in 1960 has a wide future of application due to the monochromatic frequency light produced and high interference and diffractive properties. It paves a way to use semi-millimeter waves to visible light which is still in the blank region on the frequency spectrum in radio electronics. Furthermore, from the point of view of fundamental theory, quantum electronic instruments can contribute to confirm experimentally Einstein's relativity and other theories.

According to this information, by using methods of quantum electronics a new international standard of measurements probably will be established. The chairman of French Observatory, Danjon, suggested to use the wave length of an electromagnetic wave produced in vacuum from the transition $2P_{10} \rightarrow 5d_5$ of Fr as a standard length during the conference of measurements held by French Scientific Academy in October 1960.

From the above-mentioned, quantum electronics is very closely related to national economics, national defense, and basic scientific research, and it is a new science with powerful strength.

One of the achievements of quantum electronics is the production or story of a system of new quantum instruments and some of them have been very useful in practical application. Therefore, in the present paper we emphasize this point and introduce such applications.

Quantum Electronic Instruments and Their Applications

Due to the rapid development of quantum electronics, we have had many kinds of quantum radio instruments in addition to the ones represented by an ultra-low-noise microwave quantum amplifier and a high-stability atomic clock and molecular clock. Recently, new products such as the strong interference light generator, light amplifier, light regulator, light rectifier, light radar, etc., are being produced. This is one of the main developments of quantum instruments. Furthermore, some improvements are being made on the new instruments, such as, to increase broad width of gain to increase the stability, etc. Recent conditions are: on the one hand, quantum instruments are gradually being utilized in practical applications, and on the other hand, new wave-length regions are undergoing rapid development. The following are introductions to some quantum radio instruments.

A. Atomic Frequency Standard

For a long time scientists have considered the periodic motion of particles in atomic and molecular systems as the foundation of high-stability oscillators and precise clocks. Due to the electromagnetic field produced from the motion of electrons, methods of observation and measurement are established. From the principle and methods mentioned above, several atomic frequency standards have been invented during the past years.

1. Oscillator type:

The ammonia molecular clock, for example, utilizes the vibration of ammonia molecules. An ammonia molecule is just like a polyhedron. In Figure 1.1.1, three hydrogen atoms are on the base and one nitrogen atom on the top. The nitrogen atom, under no external force, suddenly turns to the position N' from position N . This motion is called inversion. In classical mechanics, this kind of motion can not be explained. According to quantum mechanics, we know that this inversion will affect the energy of the ammonia molecule and a portion of energy levels will become single units by pairs, see Figure 1.1.2. These energy levels are usually called inversion energy levels. When the transitions between the inversion energy levels of an ammonia molecule are induced, an electromagnetic wave of frequency about $24,000$ mega cps will be radiated or absorbed. Speaking concretely, a nitrogen atom vibrates up and down at the rate of about 24×10^9 times per second. This forms the "tick-tack" of the molecular clock.

The working process of an ammonia molecular oscillator is as follows: The two kinds of ammonia molecules with a high energy state and a low energy state pass from a molecular source through a section of

molecular beam from a nozzle formed by many thin tubes in 0.1 - 1 mm Hg, and are emitted to a resonator through electrostatic division electrodes. The division electrodes consist of several cylindrical conductors on which 10,000 - 10,000 volts are applied alternately. Therefore, a non-uniform electric field is produced in the neighborhood of the axis. The ammonia molecule dipoles are interacted with the force and the low-energy state molecules fly to the region of the higher electric field. Since the wall is at the temperature of liquid nitrogen (77° K), the low-energy state molecules bombard the wall and condense. The high-energy state molecules concentrate in the neighborhood of the axis and proceed into the resonator and radiate by stimulation of the electromagnetic wave in the resonator. A microwave signal produced by the oscillation is emitted from a coupling device to be used as a signal of frequency standard.

This kind of ammonia molecular oscillator has precision to 3×10^{-11} corresponding to the error of one second per 1,000 years. The stability at a short time is $\pm 2 \times 10^{-12}$ /minute, 10^{-13} - 10^{-14} /sec. Output power is 10^{-9} - 10^{-10} watts. Under ordinary conditions, it requires a vacuum, cooling, and high voltage equipment, hence, it can be used only as an original frequency standard (8) in laboratories. However, today some small ammonia frequency standards are produced. They can be put in the aircraft. They weigh about 15.3 kg. Under a 30-gram acceleration, their stabilities are not lower than 5×10^{-10} (9).

Recently there have been established more quantum frequency standards which are made of other working materials. For example, there is hydrogen atom frequency standard of oscillatory type with a working frequency of about 1,400 mega cps of precision 10^{-13} and accuracy about 10^{-13} - 10^{-14} (10). Besides, there is another one to use inversion energy levels ($J = 6$, $K = 5$) of NH_3 with a working frequency 18 cm wavelength (11). A molecular beam oscillator has a 3 mm wave length (12) by using the spin energy levels of HCl . In these works primitive experimental results have been obtained.

2. Atomic beam type: (13a, 13b)

The cesium atomic clock belongs to this group. Figure 1.2.1 shows the working principle of this atomic clock. The emitted harmonics from a quartz oscillator stimulate an atomic beam resonator tube. The latter sends an error signal in proportion to the difference between the frequency of the oscillator and the center frequency of the resonance of a cesium atom. This signal, after sufficient amplification can be used as a control signal to control the frequency of quartz oscillation.

The physical properties of atoms of alkali metal depend mainly on the nuclei and the outermost valence electron. The interactions among the inner electrons have been cancelled. Figure 1.2.2 shows the classical

diagram of a cesium atom. The nucleus is surrounded by a magnetic field which is shown with dotted lines. The valence electron is also a magnetic particle located on the horizontal dotted line orbit. Consider that the motion of the valence electron in a magnetic field due to the nucleus is just like the oblique motion of a top on a horizontal plane. The spin axis corresponds to the central axis of the top. The direction of the nuclear magnetic field corresponds to the plumb line. The electron spins and the spin axis precesses around the nuclear magnetic field like the top motion, see vector diagram in Figure 1.2.2. In physics, this kind of motion of the valence electron in a cesium atom is called the Larmor precession. The cyclotron angular frequency ω_L is equal to the nuclear magnetic field strength at the location of the electron, H_N , multiplied by the ratio of the magnetic moment of electron, μ_B , and the mechanical spin, \hbar . This frequency is independent of the angle between the magnetic moment and the nuclear magnetic field. This forms a foundation of the frequency control. As a matter of fact, due to their quantum mechanical property in a nuclear magnetic field, the electrons only have two directions: one parallel to the nuclear magnetic field and the other opposite to it.

At the location of the valence electron, the nuclear magnetic field strength of cesium, for example, is about 3,000 gauss and the corresponding cyclotron frequency is 10^{10} cps, i.e., in the range of 3 cm wavelength.

Now we study briefly the stability and the repetition of such atomic motion. The magnetic moment and the mechanical spin moment of an electron are its basic character and the same for all electrons. Furthermore, all cesium nuclei have the same magnetic property. If there is no disturbance, the nuclear magnetic field strength at the locations of valence electrons in all cesium atoms are the same. Besides this, it is possible that the external magnetic field together with the nuclear magnetic field can affect the cyclotron frequency. We discuss this problem by using Figure 1.2.3.

$$\omega_L = 2\pi\nu_L = \frac{\mu_B}{\hbar} H$$

$$H = \sqrt{H_N^2 + H_c^2} = H_N \left[1 + \frac{1}{2} \left(\frac{H_c}{H_N} \right)^2 + \dots \right]$$

$$\begin{aligned} \nu(H) &= \frac{1}{2\pi} \frac{\mu_B}{\hbar} H_N \left[1 + \frac{1}{2} \left(\frac{H_c}{H_N} \right)^2 + \dots \right] \\ &= \nu_L(0) + \frac{1}{4\pi} \frac{\mu_B}{\hbar} \frac{H_c^2}{H_N} \end{aligned}$$

Let $H_0 = 1/20$ gauss, then

$$\frac{f(H_0) - f(0)}{f(0)} = 1 \times 10^{-10}$$

To the whole atom, the valence electron together with the nuclear magnetic field produces a combined magnetic field. Except for the two inner directions of the valence electron, the atom is considered as a whole and we can assume one of many possible directions of the any external magnetic field. One of them, which is most useful to the stability of the frequency, is the external magnetic field perpendicular to the nuclear magnetic field. The external magnetic field, H_0 , added vectorally to the nuclear magnetic field, H_N , forms an effective magnetic field, H' , at the location of the valence electron. Usually, the external magnetic field is much smaller than the nuclear magnetic field. See the equation above. The result shows that the effect of the external magnetic field on the cyclotron frequency is only to a square term. If the external magnetic field is $1/10$ gauss, the effect is only 1×10^{-10} cps. The external magnetic field changes $1/100$, the frequency changes about 1×10^{-12} . Consequently, this location has little effect due to the external magnetic field.

Now we discuss the effect of the external radio-frequency magnetic fields on the valence electron. Figure 1.2.4 shows a linearly polarized radio-frequency magnetic field perpendicular to the nuclear magnetic field. On the upper part of the figure the linearly polarized radio-frequency magnetic field has been decomposed into left and right circular two polarized components. When the circularly polarized component and the cyclotron electron have the same direction, and the frequency of the r-f magnetic field is equal to cyclotron frequency of the electron, the field vector synchronizes with the electron. From point of view of rotation system, the r-f field is like a d.c. field acting on the electron and makes the electron reverse the direction in the nuclear magnetic field and the electron absorbs the energy of the r-f magnetic field. The opposite circularly polarized field has no action.

An atomic beam resonator tube is shown in Figure 1.2.5 schematically. All elements are sealed in a high vacuum tube. The cesium atoms pass through a nozzle to produce an atomic beam. In the incident atomic beam the atoms have their directions and the valence electrons have their two possible directions. Due to the unhomogeneous strong magnetic field, the valence electrons whose directions are the same as the direction of the nuclear magnetic field will separate from another group of electrons. The former ones pass through a microwave resonator and meet a radio-frequency pulse signal, $P(f)$, emitted from the controlled oscillator.

There is another unhomogeneous magnetic field which splits the atomic beam and sends the cesium atoms of the opposite direction to the detector. If the frequency of the stimulation power deviates from the resonant center frequency, then the opposite-direction atomic beam varies with this deviation. The detector transfers the atomic beam into positive ion current as an output error signal to feed back to the controlled oscillator. The resonance curve of the resonator tube is shown as in the figure. Its corresponding peak is related to the uncertainty principle in quantum mechanics.

The accuracy of this kind of cesium atomic beam frequency standard is up to $\pm 1.5 \times 10^{-10}$ and stability to $\pm 2 \times 10^{-11}/\text{sec}$ (15). The atomic beam is rather long, so vibrating and accelerating should be avoided. The inside of the resonator needs a homogeneous weak magnetic field, but at the outside of the both ends of the resonator, an unhomogeneous strong magnetic field is required to split the atomic beam. The entire atomic beam tube needs a rather large-sized vacuum. Consequently, this standard is only used in laboratories or with fixed location for a primary frequency standard.

Today there is precise atomic frequency standard made from the vapor of thallium, i.e., the so-called thallium clock. Frequency is about 2×10^{10} cps (15). Besides this, there is another type using the rotation energy levels of $\text{H}^{13}\text{C}^{15}\text{N}$ whose working wavelength is 3 mm, and some primary experimental results were obtained.

3. Vapor bubble types

This is the small type of frequency standard using light stimulation and light detection. A block diagram is shown in Figure 1.3.1. The principal elements are a short-period high-stability quartz oscillator, phase modulator, vapor bubbles to produce the transitions of atom, phase rectifier, and feedback circuit which locks the frequency of the quartz oscillator to the resonance frequency of the transitions of atoms.

The signal-to-noise ratio of the detected wave is proportional to the number of distribution of atoms of transition energy levels. To stimulate with light can increase this ratio.

The advantages of this kind of frequency standard are: independence from vibrating and accelerating, light weight, small size (for instance, the rubidium, Rb, atomic clock has a weight of 9 kg, size $15,000 \text{ cm}^3$ (15); the cesium, Cs, atomic clock lighter than 14 kg, power consumed less than 50 watts (17)). They are fit for satellites, rockets, etc. They can also be used as small secondary frequency standards in laboratories. Recent achievement: a light portable Rb vapor frequency standard

transistorized, small in size, weight light, power consumed less than 10 watts, and the stability of frequency keeps 1×10^{-11} (18) or better within one month.

It is possible to use this small frequency standard to confirm Einstein's general relativity. To put an atomic clock in a satellite and another one on the earth can prove the required result of the experiment by comparing the difference between these two clocks.

In order to narrow the band width of the resonance line of an atom caused mainly by the Doppler effect, we can fill the vapor bottles with a non-magnetic buffer gas such as argon, neon, or xenon. By using this method, the line width can be narrowed to a width of Rb^{87} to 20 cps at room temperature. The corresponding Q value is 3×10^8 . Then add buffer gas, but cause the center frequency to shift. This shift is a linear function of the pressure. It was discovered that the light gases such as hydrogen, neon, and helium produce frequency shifting to high frequency, while argon, krypton, and xenon produce the opposite frequency shifting. For example, Cs^{133} with 75% argon and 25% neon can have a maximum pressure frequency shift.

No matter what kind of an atomic clock with high stability and high accuracy we have, it must meet the following three requirements:

- (1) The center frequency of transition of an atom or molecule must be very stable and independent of the electric field, magnetic field, pressure, temperature, mechanic vibration, and acceleration, etc.
- (2) The narrower the width of resonance line, the better.
- (3) The higher the ratio of signal-to-noise of the rectifier, the better.

In addition to the three types of atomic frequency standard mentioned above, in 1959, during the American Quantum Electronics Meeting, N. Bloembergen suggested the possibility that a solid quantum amplifier can be used as a time standard (19). Its advantage is that the frequency drag in the resonant cavity can be avoided, and at low temperature it works very stably for a long time, output power larger, and noise from spontaneous radiation can be neglected. However, up to now this kind of frequency standard has not been achieved.

Concerning this, refer to the literature (19, 20).

B. The Production and Amplification of Strong Monochromatic Light

Monochromatic visible light (wavelength ca. $4,000 \text{ \AA} - 7,000 \text{ \AA}$) and infrared (wavelength ca. $0.7 \text{ \mu} - 100 \text{ \mu}$) are electromagnetic waves of short wavelength. Human beings have controlled and used widely the production and amplification of usual radio waves. But the production and amplification of monochromatic visible light and infrared were not solved until the invention of laser* and iraser** recently. This is a new era of a combination of radio physics and optics. T. H. Maiman announced in July, 1960, that a laser was born(21).

In laser, a negative temperature working state in a quantum system of material is used. The important feature of the induced emission is for it to be the same frequency, the same phase, and the same directed oscillation as the incident light. Therefore, laser can produce a very narrow (for instance, 0.01°) monochromatic beam of high intensity (energy highly concentrated to make the light pressure up to 10^6 atm.), with high purity. It forms a strong monochromatic interference light source and makes light really amplified. The birth of laser has its important meaning in national defense, scientific research, and national economics.

1. Lasers (monochromatic interference light source):

Recently, several different types of laser have been produced successfully. The working materials are gases as well as solids.

a. Using dilute ruby(23, 24), $\text{Al}_2\text{O}_3 + 0.05\% \text{ Cr}^{3+}$:

A thin rod made of a concentration of 0.05% ruby, both ends parallel to each other with a small hole (or electroplated with semi-permeable film) electroplated with silver form a resonator of Fabry-Perot interferometer. The rod is wrapped in a helical arc lamp. When

* Laser -- Light Amplification by Stimulated Emission of Radiation.

** Irsaser -- Infrared Amplification by Stimulated Emission of Radiation.

Recently some authors suggested to use ~~laser~~ and ~~laser~~, instead of laser, Laser and Irsaser, to represent Electromagnetic Wave Amplification by Stimulated Emission of Radiation and Electromagnetic Wave Oscillation by Stimulated Emission of Radiation respectively. The meaning of ~~Maser~~, Laser, and Irsaser is ambiguous.

green light ($5,600 \text{ \AA}$) and blue light ($4,100 \text{ \AA}$) stimulate the red, the ruby absorbs the energy inside a very broad frequency band. The chromium ions in the ruby are stimulated to high energy levels, see Figure 2.1.1. Afterwards, through nonradiation transition, the levels go down to 8 energy levels and re-radiate a light of very narrow frequency band such as $6,929 \text{ \AA}$ and $6,943 \text{ \AA}$ red light, and then return to the basic levels. This process uses the principal lines of the ruby and requires much power to stimulate. A pulse mercury arc lamp needs 1×10^6 watts of pulse power. The maximum output of pulse power is 10 kilowatts. The intensity of the emission lines of a ruby varies with the power of stimulation. A simple process to produce strong monochromatic interference light is the following: A photon of proper frequency stimulates many atoms in excited states to produce induced emission. The electromagnetic waves from the induced radiation of these atoms are coupled to the resonator and radiate synchronously and not like that of ordinary lights which radiate individually and at random. Between the both end mirrors of the cavity of interferometer type, sufficient energy is kept to produce the proper action -- the continuous reflection between mirrors during every round of the process have more radiation to strengthen the axial output of the light. No axial light passes through the coupling hole (or semi-permeable membrane) to the outside. The radiation of other directions will be either absorbed or escape to outside the wall.

Now, many research units have produced ruby lasers successfully, some of them have been manufactured. The following is a simple introduction to its working principle.

Figure 2.1.2 shows the energy levels of ruby. In the quantum system there are two transitions: One is the spontaneous transition (A), and the other induced transition (W). Spontaneous transition is the transition between energy levels of particles under no external action. When a particle makes the spontaneous transition from a high energy level to a low energy level, it is possible to emit photon to produce spontaneous radiation. The intensity of spontaneous radiation is proportional to the cube of frequency. Hence, it is important in the range of visible light and infrared. In microwave range, except noise problems, generally the spontaneous radiation can be neglected.

In the figure, $W_{13} = W_{31}$ and $W_{12} = W_{21}$ are respectively the probabilities of induced transition between energy levels 1 and 3 and between 1 and 2. They are proportional to the intensity of the light waves. In ruby lasers, a very strong stimulation light source is used (i.e., W_{13} very large), ν_{13} is ca. $5,600 \text{ \AA}$, the stimulation temperature is ca. $4,000^\circ \text{ K}$. W_{21} is rather small in comparison with W_{13} . The intensity of light of frequency ν_{21} is determined from the condition between the energy levels 2 and 4. W_{21} determines the emitted power of the laser.

A_{31} and A_{21} are the probabilities of spontaneous transitions to the first energy levels from the third energy levels and second energy levels respectively. They and the probabilities of induced transitions satisfy Einstein's relations. From the absorption coefficient of light between two related energy levels, the probabilities of spontaneous transitions can be determined. According to T. P. Malozzi⁽²⁵⁾, A_{31} is ca. $2 \times 10^5/\text{sec}$. From the identity of a number of particles of energy level E_3 at equilibrium, $A_{31}N_2 = S_{32}N_3$, we can find the non-radiation transition probability, $S_{32} = 2 \times 10^5/\text{sec}$. The concentration of paracetamol in solution is usually used is 0.05%, while its relaxation time of spin crystal lattice at room temperature is ca. 5×10^{-8} second. The calculated values agree with the experimental results approximately. (25)

In order to gain amplification of quantum we have to produce an inversion of particle numbers between two energy levels in quantum system. That means the negative temperature working condition. To the quantum system we discussed, we must make the number of particles with higher energy level E_2 , N_2 , larger than that with lower energy level E_1 , N_1 . For the purpose of this we use a very strong stimulating light source to obtain $N_2 > N_1$.

The time rates of numbers of particles with energy levels (2) and (3) are:

$$\frac{dN_1}{dt} = W_{12}N_2 - (S_{21} + A_{21})N_1 - W_{21}N_1 \quad (1A)$$

$$= W_{12}N_2 - S_{21}N_1 \quad (1B)$$

$$\because S_{21} \gg A_{21} \text{ \& } N_1 \ll N_2$$

$$\frac{dN_1}{dt} = W_{12}N_2 + S_{21}N_1 - (W_{21} + A_{21})N_1 \quad (2)$$

At equilibrium $\frac{dN_1}{dt} = \frac{dN_2}{dt} = 0$, then (1B) becomes

$$S_{21} = W_{21}N_1 \quad (3)$$

Equation (2) becomes

$$W_{12}N_2 + S_{21}N_1 = (W_{21} + A_{21})N_1 \quad (4)$$

Substituting Equation (3) into Equation (4), we have

$$\frac{N_2}{N_1} \approx \frac{W_{12} + W_{21}}{A_{21} + W_{21}} \quad (5)$$

$$\therefore W_{12} = W_{21}$$

From Equation (5) we know that when $W_{12} > A_{21}$, then $N_2 > N_1$. At this time, the quantum system has amplification for light frequency ν_{21} .

If we investigate the energy levels further, we find that 2E splits into two energy levels, $2E_1$ and E , a distance of 29 cm⁻¹ apart. Therefore, the two wavelengths of radiated red lights from $2E_1$ and E to the basic energy level $4E_2$ are: $\lambda_2 = 6,929 \text{ \AA}$, and $\lambda_1 = 6,943 \text{ \AA}$, respectively.

In order to explain the distribution condition of particles when stimulating light source exists and to estimate quantitatively the required intensity of the stimulating light source, we introduce an idea of equivalent temperature, T_e of light source, and suppose that the specimen should be optically thin. The light source is approximately a black body. From the theory of radiation the following relation can be obtained:

$$T_e > \frac{h\nu_{21}}{k \ln \left(\frac{S_{E_1}}{A_{21}} + 1 \right)} \quad (6)$$

The present problems are:

1) Interference is not quite good. Its improvement will be by:

(1) Working with liquid nitrogen will increase interference⁽²⁶⁾.

(2) Using a precise resonator of interference type (degree of parallel should be less than wavelength) will increase interference. Recently some authors studied a co-focusing structure^(27a, 27b). This kind of resonant cavity consists of two spherical reflectors which are separated by a distance equal to the outer radius of curvature and have a cross-section through which an image will be formed to radiate. The loss of diffraction of this kind of resonator is small, and the optical

adjustment is not critical as in the case of Sarrus-Kerol interferometer where the plane mirror of the resonator should be adjusted precisely. Other advantages of this kind of resonant cavity are:

i). Cooperative independence of vibration.

ii). Do not need as precise a surface as some plane types do.

iii). The material of light emission required is smaller than that required by the plane types. This means that the power of stimulation can be decreased.

This structure can be used widely to quantum amplifiers for the wavelength of a millimeter to visible light.

2) A large amount of heat produced from the arc discharge lamp shortens the working time period of the amplifier. Up to now, the pulse work can only last a few microseconds and the efficiency of energy inversion is not high.

b. To use concentrated ruby (26), $Al_2O_3 + 0.5\% Cr^{3+}$:

The working process is basically the same as in the previous case. The only difference is that the concentration of ruby is 0.5% Cr^{3+} , the line used is the company line of ruby, or called R line (at the distance about 100 cm-1 from the basic level), the red light emitted are 6909 Å and 7,441 Å, and the required power of stimulation is smaller, and the stimulation is made by a continuous mercury arc. The working process is made with liquid nitrogen.

c. To use calcium fluoride with an impurity of samarium (29), $CaF_2 + 0.1\% Sm^{2+}$:

This is a new type of instrument using ions of a rare earth element. It will work for a continuous wave. Its efficiency of inner energy inversion is several hundred times that of ruby. Hence, the required power of stimulation is smaller. The first calcium fluoride light amplifier is only partially stimulated to emit light. Its designer thought that the improvement of reflection from the both ends of the interferometer would increase the amount of illumination of the material and work on continuous waves. Since the rays of laser are reflected many times on both end surfaces of interferometer, a little increase in the reflection will improve the work on pulsed and continuous waves very much. So a further improvement is a problem of optical design. The working wavelength of this instrument is 7,082 Å. It has to work under the temperature of liquid helium.

It should be pointed out that the efficiency of present lasers using a crystal as a working material is not high. This is due to the un-homogeneous composition of the material. The improvement on crystals will improve the properties of lasers.

- d. To use calcium fluoride with impurity of europium (30), $\text{CaF}_2 + 0.1\% \text{Eu}^{2+}$;

The working material is a flaky specimen. It will emit blue light of wavelength 4,250 Å when the specimen is stimulated by the H_γ line of ruby. Two processes of quantum stimulation are observed.

In addition to the working materials mentioned previously, the use of other materials has been reported. Mercury-zinc gaseous discharge has a working wavelength of 6,263 Å⁽¹⁵⁾. A glass-like organic mixture, benzophenone, $[(\text{C}_6\text{H}_5)_2 \text{CO}] + \sim 0.02\%$ naphthalene (C_{10}H_8), produces stimulated fluorescence of wavelength 4,700 Å². Its working mechanism is like that of a helium-neon mixture. Benzophenone corresponds to helium and naphthalene to neon.

2. Lasers:

Materials which can be used for lasers include solids, certain vapors, mixing gases, and semi-conductors. The methods of stimulation include arc, self-discharge, etc. The working wavelength is from 10,000 Å to far from infrared. The maximum output power is a magnitude of watt. It is possible to work on equal-amplitude waves. The recent problems are how to increase the output power and how to prevent the corrosion of alkali on the container.

- a. To use mixing gas of neon-helium⁽²⁶⁾;

A newly designed gaseous light amplifier for continuous waves has a different stimulating structure from the ordinary ones. The amplifier consists of a tube 1 m long in which neon and helium mixing gases are filled. It looks like an ordinary neon discharge lamp. The stimulation is made from a non-electrode high frequency discharge of 28 mega cps. The energy coming from the inner discharge stimulates helium atoms to higher energy levels. Under normal conditions it does not radiate. The neon atoms in the mixing gas collide with the stimulated helium atoms, and through the collisions the energy transfers. The neon atoms themselves have the possibility for stimulation. They are under a working condition of negative temperature, and radiate energy as a continuous energy source. The energy levels of neon-helium are shown as in Figure 2.2.1.

* Phys. Rev. Lett., 1962, 8, No. 23-25.

The light beams reflect back and forth between the semi-reflecting surfaces on the two ends of the gas tube. They strengthen after each reflection. Some of the beams exit through the end plate to form an output of a very narrow interference infrared continuous light beam (the spectrum width is about 1×10^{-5} of other interference light sources). When energy is radiated, some neon atoms drop to very low energy levels just as a neon lamp emits red-yellow light spontaneously. The stimulating power is about a fraction of watt. The output power is ca. hundredth of watt. Increasing the diameter of the tube can increase the output. The working temperature is not high, even when touched with the hand it does not feel too warm. Working wavelengths are from 11,000 Å to 12,000 Å. We have five of them. Using the Kerr Cell instrument a telegraph has been tested. The frequency width adjustment has been done successfully up to 60 msec ops. Using other methods it is possible to work to thousands msec ops. We can use this kind of laser to transmit a sizeable signal in a tube. The loss is very small. At corners, reflecting mirrors can be used. This is an important development for the telegraph.

- b. To use calcium fluoride with an impurity of uranium⁽³²⁾,
 $\text{CaF}_2 + 0.1\% \text{U}^{3+}$

Uranium ions of valence 3 are one of the important materials of the new infrared instruments. Using calcium fluoride as the base is a most common optical material. The wavelength is 2.5 μ . This kind of laser works with liquid oxygen continuously, and its wavelength is 2.613 μ ¹⁾.

- c. To use calcium tungstate with impurity of neodymium⁽³³⁾,
 $\text{CaWO}_4 + 0.11\% \text{Nd}^{3+}$

Working material is calcium tungstate CaWO_4 with an impurity of 0.11% Nd^{3+} which is made into a rod with two spherical ends, one of which is of 5% transparency. It is stimulated by a GERT 52h xenon lamp. Work is done at 77° K or room temperature. The strongest observed emission line is $^4\text{F}_{3/2} \rightarrow ^4\text{I}_{11/2}$, and the wavelength is 1.063 μ . To this specimen, at room temperature, the threshold value of stimulated emission is ca. 5 joules; while at 77°K it is ca. 3 joules.

- d. To use calcium tungstate with an impurity of thallium²⁾,
 $\text{CaWO}_4 + 0.5\% \text{Tl}^{3+}$

The specimen is cylindrical with spherical ends. The stimulating lamp is GERT-52h, T = 77°K. The stimulated fluorescence has $\lambda = 1.951 \mu$. The threshold value is 125 joules.

- e. To use calcium tungstate with an impurity of holmium³⁾,
 $\text{CaWO}_4 + 0.5\% \text{Ho}^{3+}$;

At $T = 77^\circ \text{K}$, a stimulated fluorescence of $\lambda = 2.045 \mu$ was seen. The threshold value is 300 joules.

- f. To use calcium fluoride with an impurity of neodymium⁴⁾,
 $\text{CaF}_2 + \text{Nd}^{3+}$;

A cylindrical specimen with spherical ends emitted infrared of 1.046μ at 77°K . The threshold value is 80 joules.

- g. To use strontium molybdate with impurity neodymium⁵⁾,
 $\text{SrMoO}_4 + \text{Nd}^{3+}$;

$T = 77^\circ \text{K}$, working wavelength is 1.6643μ , and threshold value is 1/2 joules. At room temperature the threshold value is 125 joules.

In addition, there is a paper reporting to use Ba Crown glass with an impurity of neodymium, and some author suggested the use of In-Sb semiconductor⁽¹⁵⁾ which is lesser of a cyclotron resonance type. Using a very strong resonance magnetic field can produce the Landau energy level and using light to stimulate electrons can put them into higher energy levels, then we try to produce infrared radiation. It requires a strong magnetic field and low temperature equipment. It can be used as a monochromatic light source in the region of semimillimeter waves and infrared. The large loss of energy in the semiconductors makes it difficult for applications.

Furthermore, there is another working material, $\text{BaF}_2 + \text{U}$. The working wavelength is 2.7μ ⁽¹¹⁾.

Besides the aforementioned interferometer and cyclotron resonance types, there is another idea of a fiber type of light amplifiers⁽¹⁵⁾. The latter does not work with the pattern of interferometer, but the light propagates along a thin thread. The thin thread is used as a controlled non-axial pattern to guide the lightwaves, and its directivity has the same magnitude as that of interferometer type. Ruby has been used into thin threads, but not very thin. Some authors suggested that glass with an impurity of a rare earth element is better. It requires a very long thin thread, so the technique has suffered some difficulties. So far this type of laser has not been successfully made. Some other countries are now studying a travelling wave type of laser⁽⁶⁾.

No matter what type of laser, the common requirements are the following: (1) high power output (for transmission it is very important; but for receiving, a constant output is all right). (2) working in a continuous wave (in some applications a definite pulse is also available), (3) good coherence, (4) narrow band width output of frequency, (5) high directivity, (6) will working under room temperature.

3. Possibilities of wide applications of lasers(15, 16):

According to present knowledge, the success of the primary production of a strong monochromatic source and light amplifier hints at the possibilities of the following applications:

a. National defense and military:

Light radar and long-distance photographs are made by using a very narrow and high strong light beam (0.01°) and extremely high modulating power. A collidar(14-16, 17) has been invented. It can be used to photograph an object at a very long distance. The principal part of a collidar is a light quantum oscillator which can produce a sharp focused light beam with a strength of a certain or coherent light 1×10^4 times as that of sun light. The wave band width of the experimental system is ca. two orders of magnitude narrower than that in ordinary radar. If a better crystal is used, the band width will be narrower. Theoretically, the wave band of the output light from the oscillator itself can be up to 7μ radians (about 0.004°). The narrower wave bands can distinguish an interval of 30 cm at a distance of 9 km (working wavelength 6,963 Å, pulse 3 milliseconds). The present light radar is limited by the following factors:

Wave band width: More high quality crystal is required to produce a narrower band width wave.

Light filter: Filter can improve the signal-to-noise. The recent filter works only up to 1 K, and does not satisfy the requirement.

Stimulating crystal: Better stimulating crystals and improvement of method to stimulate crystals are required.

Scatter and diffusion: Scatter and diffusion of light waves due to atmosphere limit the application of light radar on the ground.

Collidars are estimated to be used efficiently only in space, without an atmosphere problem. Their advantages are: angular resolving power high, light weight, power consumed small, and long distance action.

Today portable light radars are available.

* Collidar -- Coherent Light Detection and Ranging

b. Communications:

Using monochromatic light and monochromatic infrared we can have very long distance radio communications free from an electrostatic field, interference, and detection. They can be used for communication, broadcasting, and television between the earth and other planets, and artificial satellites in space. Their channels can be increased indefinitely. The advantages of using light communication in underground tubes are: wide communication frequency bands width to give many channels, strong directivity, small loss due to tube walls, and easy production of tubes.

c. Basic research on physics:

The appearance of a coherent light source gives the possibility of a lot of new research. Using lasers we will develop basic research on physics. When a strong coherent radiation shines on a molecule or an atom, some unknown resonance effects will be more important. Possibly, strong vibrations produced are sufficient to overcome the binding forces of molecules. The research on non-linear large amplitude of molecular oscillation may be the important problem in the new field. In addition, using coherent light radiation we can construct accelerators for charged particles^(9b), and study properties of materials in strong electric fields, etc.

d. Medicine and hygiene:

(1) Surgery: A light knife, a tool for surgery by using monochromatic light, can do the job faster than any ordinary surgical knife does, and can cut through tissue more accurately than that achieved by present surgery.

(2) Sterilization: Strong monochromatic light can produce high local temperatures and can be used for surface sterilization and cell vaporizing of an individual part. It also kills, sterilizes, and burns cells in a small region. In radioactive cures, it will strengthen the effects of γ -ray or radioactive isotopes.

e. By using monochromatic coherent light we can make very high resolving power optical instruments which can not be achieved by present optical instruments. Pure monochromatic light is a powerful tool for studying accurately the inner structure of materials and also for precise measurements.

f. A new method of standardization of length measurement thus will be established and precise length measurement for long distances can be done.

g. Chemical engineering and metallurgy: Using strong light sources to stimulate molecules will catalyze many new reactions. It will produce new chemical reactions and quick spot-welding and other kind of welding. This is important to mechanical engineering, nautical engineering, and aeronautical engineering.

h. Precise process on different materials and very small parts.

1. More foresighted ideas: (1) Used as weapons against continental missiles, rockets, and aircraft. (2) Used as a "death-ray" weapon due to the killing property of highly concentrated energy. (3) Used as laser fast computers. (4) Used as defense weapons to survey, communicate, detect, and under-water detection (19, 39, 41). By using the property that the waves with band width 10 \AA in the green or yellow-green part (wavelength $5,100 \text{ \AA}$), electromagnetic window, have the smallest loss in sea water, surveying and communicating can be done. There exist many difficult problems in surveying by hydroacoustical methods, especially the detecting of ultra long distance and high accuracy, for which a very complicated design is required. Recently, some authors have studied light amplifiers for waves in the blue-green region as generators of focused wave beams to penetrate sea water. Scattering wave beams will be a powerful tool in under-sea communications and high-accuracy surveying. The decay of a light wave in sea water is caused principally by the absorption by materials in the water. The diffusion due to suspensive particles and reflection along the propagating path of light makes light level higher, so that the object can not be distinguished easily. This is equivalent to lowering the signal-to-noise. This becomes a principal reason why light in water can not propagate as far which is caused by a receiver with insufficient sensitivity. In early experiments, a 150-watt mercury lamp was used. A focused parabolic surface reflector formed a narrow wave beam. A receiver used a parabolic reflector to focus the light to a photomultiplier. The greatest distance one way was ca. 1 km. In order to overcome diffusion, an efficient scanning device should be studied.

Some authors suggested a term, vedac (visible energy detection and ranging), for this kind of amplifier of visible light.

According to reports, the Russians have discovered two electromagnetic windows in sea water in the region of far infrared, whose wavelengths are $390,000 \text{ \AA}$ to $430,000 \text{ \AA}$. The main problems on such quantum amplifiers for this region are to find some proper materials.

The generation and amplification of monochromatic light is one of the newest achievements of quantum electronics. From the point of view of development, the aforementioned possibilities have a broad future.

C. Masers

The general microwave tubes work on the basic principles of radio-electronics. It seems that they use the interchanging energy of interaction between free electrons and an electromagnetic field. Recently, this tradition has been broken and the application and research on binding electrons is beginning. This work generally is related with energy changing of electrons in solid or molecule, of which the most interesting phenomena is that they will behave according to quantum mechanic properties. Binding electrons show their new property of stimulation which free electrons do not have. The typical quantum property observed is that electrons can only exist on discrete (i.e., so-called quantized) energy levels and have definite energies. In the quantum system, there is no noise from a hot cathode or electron current like that in electron tubes. Quantum amplifiers work under low temperatures. The lower the temperature is, the better the result. Therefore, they have a very low noise level and a very high sensitivity.

Masers can be classified into two kinds: gaseous and solid. Recently, the majority of super-low-noise amplifiers have been the solid type and more successful. Working wavelengths are from a meter to a millimeter. Working processes are by continuous wave and pulse.

1. Solid masers:

Solid masers have many different working processes, such as in two-energy-level solid masers, high-frequency-stimulated masers, three-energy-level and four-energy-level maser, which have the same principle as in three-energy-level ones, e.g., push-pull, push-push, masers. However, the most basic is the three-energy-level. We discuss this kind of working principle briefly (for detail, see Ref. 3.1a-b).

The amplification of three-energy-level masers is done by stimulated emission of lower energy levels of paramagnetic ions under amplifying signal frequency. At thermal equilibrium, since the number of particles of energy levels in a molecular system or a paramagnetic system is distributed according to Boltzmann's law, the number of particles of lower energy level is always larger than that of higher energy level (see Figure 3.1.1a). They always absorb external electromagnetic waves. For the purpose of changing the absorption system into an emission system we must destroy Boltzmann's distribution to obtain a condition that the number of particles of a certain higher energy level is larger than that of lower energy level. There are different methods to increase the number of particles of high energy level, one of the more efficient of which is auxiliary stimulation in the three-energy-level system. Figure 3.1.1b shows the principle of this method.

Energy levels 2 and 3 are the basic energy levels. The distance between them determines the working frequency ν_{23} . Energy level 1 is an auxiliary energy level. The auxiliary stimulating frequency ν_{13} makes a transition between energy levels 1 and 3. At thermal equilibrium, the number of particles of lower energy level 1 is larger than those of particles of higher energy levels 2 and 3. Due to the relation of stimulated transition which occurred between energy levels 1 and 3, the number of particles of energy level 3 is increased. Stimulated radiation must have a high frequency field intensity such that a saturation phenomenon can be obtained ($n_1 = n_3$), then the numbers of particles of energy levels 1 and 3 can be made equal. The following three cases can occur in saturation phenomenon:

- i. The number of particles of energy level 3 is larger than that of particles of energy level 2, i.e., $n_3 > n_2$ (3.1.1b).
- ii. The number of particles of energy level 2 is larger than that of particles of energy level 1, i.e., $n_2 > n_1$.
- iii. The numbers of particles of three energy levels are equal, i.e., $n_1 = n_2 = n_3$. In this case, the system can not emit energy.

In saturation, if the number of particles of energy level 3 is larger than that of particles of energy level 2 (i.e., $n_3 > n_2$), then this system can emit energy quantum under frequency ν_{23} . That means that, under the action of electromagnetic wave of frequency ν_{23} , the system emits energy with the same frequency and strengthens the external electromagnetic wave to produce quantum amplification. For detail see ref. (13a).

According to the structure, microwave solid masers can be classified into two kinds: cavity type and travelling wave type.

a. Cavity type:

(1) Single cavity:

According to the coupling mechanism, this type can be classified into reflection type (single hole) and transmission type (double hole). When the magnetic quality factors of these two types, Q_m , are equal to the signal, Q_s , respectively, then

$$(\sqrt{GE})_s > \frac{1}{2} (\sqrt{GE})_m$$

where G is power gain; B , band width; \hat{c} , representing double hole; 1, single hole. Because the reflection type has better properties, it is

commonly used and its cavity generally is made of metal. Sometimes, because the stimulating power is not large enough, or the requirement of an even magnetic field and small space, a very small cavity is required. Thus a gas cavity is used, which is a cavity made from a gas the surface of which is electroplated with silver. The filling factor of gas cavity is 1, and its volume is small. Its property is good (15).

The important parameter to show in masers is the product of voltage gain and band width. For the reflection cavity type:

$$\sqrt{G B} \approx \frac{h}{|Q_m|}$$

where f_0 is the frequency of the working signal.

From the equation, we can see that the product of voltage gain and band width of a single reflection cavity type maser is approximately a constant, but both cannot have the same degree of constancy. The higher the working frequency f_0 and the smaller the $|Q_m|$, the larger the product of voltage gain and band width. $|Q_m|$ is related to many factors, one of which is temperature and it is important. The lower the temperature, the smaller the $|Q_m|$. The characteristics of recent masers for several principal wave regions is shown as in table 3.1.

(2) Double cavity:

The cavity made of paramagnetic material which has the property of stimulated emission is called negative Q cavity; while the cavity without paramagnetic material which has property of pure energy absorption is called a positive Q cavity. Double cavity masers have the following two forms:

i. One negative Q cavity is combined with one positive Q cavity. The positive Q cavity produces tuning, and the Q value is low. The coupling between two cavities is very tight to produce a double-hump and to increase band width. The recent maser of wave region 3 cm (working temperature 1.2°K) has a gain band width up to 550 mcs (50a, b). Such high value obtained is probably due to the cross-relaxation effect and double cavity.

ii. Two negative Q cavities are combined together. There are two kinds of connections: Inner series, i.e., one transmission negative Q cavity is connected to a reflection negative Q cavity, see Figure 3.1.2. External series, i.e., two reflection cavities are connected together externally through an iron-oxide ring transformer, see Figure 3.1.3. This kind of double-cavity maser has the following relations:

$$\sqrt{CB} \approx \frac{1.3h}{|Q_m|}$$

In the case of inner series, when the coupling coefficient between two cavities is $K = 1/Q_m$, the unstable coefficient of amplification approaches zero.

(3) Triple cavity, multiple cavity:

The triple cavity type can also be classified into inner series and external series. The inner series type requires a larger magnetic field; while the external series type requires only several small magnets. In the latter case, if the magnetic field intensity is slightly different, an irregular tuning can be done to increase the band width. This method needs small iron-oxide ring transformers. Due to the number of the latter increases, an insertion loss will be increased.

The multiple cavity type consists of many cavities connected in series. It is a single direction amplifier using a circularly polarized wave. The four-cavity series type has a voltage gain band width product of 200 mega cps. If irregular tuning is used, the value can be up to 800 mega cps (52a). Some types have iron-oxide between two cavities; then the four-cavity type can obtain 450 mega cps (52b).

The single cavity type can not have the whole action of the characteristic line width of paramagnetic crystal developed enough because its band width is limited by the structure of the microwave. As to the material of the cavity, except metal and the gem cavity, high frequency dielectrics (no metal in the outside) can also be used by using the principle of surface waves. This kind of cavity at room temperature has a quality factor up to several thousand and is fit for millimeter waves. It is worth discussing.

The research work on masers has been developed on lines of their applications. The requirement for them is getting higher and higher. Generally speaking, there are six requirements: 1 - Large voltage gain band width product. 2 - High gain sensitivity. 3 - Low noise of system. 4 - High level of saturated power of signal. 5 - Easy tuning. 6 - Light weight and small volume.

From the point of view of electric quality, cavity type masers can only satisfy a part of the requirements. The travelling wave type masers are better.

b. Travelling wave type (53-57):

The simple principle of travelling wave type masers is the following: try to make microwave energy pass through a special microwave

structure -- slow wave structure. The energy is sent to pass a spin system of a paramagnetic material with a group velocity as slow as possible. Let the microwave energy have a maximum interaction with the spin system. If a saturated stimulating power of a proper frequency is added to the spin system, the spin system is then in a stimulation state. The energy will pass along the slow wave structure and increases with the length of the latter exponentially. In order to obtain pure single direction gain, we should use circularly polarized waves. Therefore, in a slow wave structure, in addition to the working material, we have to put iron-oxide of ruby of high concentration to confine enough positive direction gain and opposite direction decay.

The gain of travelling wave masers is about

$$G = 27.3 \frac{SN}{TQ_m} \text{ db}$$

where S is the slow wave factor, equal to C/V_g , C is the velocity of light, V_g is the group velocity of electromagnetic wave, and N is the length of the slow wave structure in the unit of working wavelength.

The band width of travelling wave masers is

$$B = B_0 \sqrt{\frac{3}{G-3}}$$

where B_0 is the characteristic band width of the paramagnetic crystal, and G is the power gain mentioned above. From the above equation, we can know, when gain is equal to 30 db, the band width of a travelling wave maser is 1/3 of that of paramagnetic crystal. Such a broad band width is one of the outstanding features of travelling wave masers.

From the point of view of instability of gain:

Travelling wave type masers: $S_g = L_n G$

Cavity type masers: $S_g = \sqrt{G}$

Comparing both, the former has much better stability. This is mainly caused by the fact that the input and output of the travelling wave type are separated from each other.

From the point of view of tuning, travelling wave masers use electronic tuning by only changing the stimulating frequency and magnetic field (e.g., at working frequency 300 mc/s and band width

20 mega cps, the tunable region will be 200-500 mega cps). It can also be designed to be single-knob tuned and the tuning is made very easy.

From the point of view of saturated level of signal, travelling wave masers use a larger crystal and require higher stimulating power, so this is disadvantageous when the power of the stimulating source is not large enough. However, it can support a stronger signal: in practical use this is one of its advantages.

From the point of view of the volume of instrument, a travelling wave maser using a larger magnet is bigger than a cavity maser. It is not so convenient in case of small instrument requirements.

The main problem of travelling wave masers on microwave is how to construct a good slow wave structure -- how to pass the electromagnetic wave with a group velocity as slow as possible through a slow wave structure as short as possible. (56, 57) The recent experimental or practical slow wave structures:

(1) Dielectric slow wave structure (58):

Using dielectric with high dielectric constant and low microwave loss decreases the velocity of the wave. For common dielectric materials, one with a high dielectric constant frequently has a larger loss. So there is a new job to find materials with high dielectric constant and low loss. Recently, by using this method, we made a travelling wave maser with a 3 cm wave band (8-10 kilomega cps) and a band width of 20 mega cps. At 1.4° K, the measured value of gain is ca. 2.4-3.2 db per cm, see Figure 3.1.4. The slow wave factor is $S = C/V_g = 15$. The process of this structure is more simple than that of other periodic structures, and it is worthy of study.

(2) Zigzag structure (59) (Figure 3.1.5):

A zigzag structure is made by a metal process, wiring, or printed circuit. The electromagnetic wave propagating along the zigzag is TM wave. Although the wave velocity is equal to the velocity of light, the group velocity along the axis of the zigzag structure is less than the latter. The slow wave factor of this method can be up to 100-150. On the upper side and lower side of the structure are rubbers with different respective concentrations. Or, on one side is ruby and on the other side is iron-cobalt. The whole structure is put in a stimulating wave guide. A proper magnetic field is added with a direction perpendicular to the direction of wave propagation. This forms a travelling wave maser. Data for the 10 cm wave band maser are: gain ca. 25 db, and band width 25 mega cps.

(3) Helix slow wave structure (40):

It usually is used in a travelling wave tube. Using it together with one of the first kind has better efficiency. In a helix structure there is a ruby. Since the electromagnetic field of a helix radiates outside, the whole helix structure is put into a ruby tube in order to sufficiently use the electromagnetic field and raise the efficiency. The helix of this kind of maser is obliquely wired, so it is difficult to make the radio-frequency field perfectly perpendicular to the d.c. magnetic field. From the point of view of process of technique, this kind of structure is easier to make.

(4) Comb structure (53) (Figure 3.7.6):

This structure consists of many identical comb teeth, and has a band pass property and no dispersion cutoff effect. On one side of the teeth is paramagnetic material, and on the other side is absorption material. The gain of the central band is

$$G = \frac{8.686 N_s}{|Q_n| B} \text{ db}$$

where B is band width, and N_s is the number of elements of resonance, i.e., number of comb teeth. From the above equation, we know that to have a high gain we must increase the number of comb teeth or decrease the band width. But the large number of comb teeth makes the structure too long (and the magnetic field can not be uniform) and is not convenient for practical case. If in a region of definite length, the distance between teeth becomes shorter and shorter, the radio-frequency field around the comb teeth will be denser and denser. Consequently, spin systems of only a few paramagnetic materials interact with the magnetic field. To get optimum working conditions of the band width the band width of the structure must be larger than that of the paramagnetic resonance. Therefore, we must find an optimum method of design. Furthermore, the comb teeth should be made identical, and every resonance element should work with high Q . The machine error should be very small. Generally speaking, the higher the frequency, the more difficult the design. The design should also consider the intrinsic loss of the structure. In addition, the bands of frequencies at input and output ends should be watched. (51) The recent level obtained: for comb structure of working frequency 6,000 mega cps, gain 23 db, band width 25 mega cps; for comb structure of frequency 2,120-2,370 mega cps, gain 30 db, band width 21 mega cps. The latter has the stimulating frequency controlled by the method of line voltage delayed by a control returning wave tube, and the d.c. magnetic field controlled by a knob. Therefore, a very

of a special alloy (such as niobium-tin alloy), at low temperature, can produce a magnetic field due to superconductivity. This has been used in sensors of L wave bands. A sensor of J cm wave band consisting of a small Dewar in which there are a permanent magnet, iron-oxide transformer, and generator, is only 35.6 cm (14") long and weighs below 5.36 kg (11.8) (62). In low temperature environment, first we have to design a durable Dewar flask which can be used for several tens of hours continuously on one filling, and stable in any position so that the liquid never pours out. The liquid surface elevation indicator also needs to be actuated properly. Other problems are such as how to supply the cooling liquid automatically and how to prevent the effect of vibration of the liquid surface on the stability of the sensor, etc. (60) The best method of liquid helium supply is to design a small recovered (closed) liquid helium cooler. One recent design weighs only 6.36 kg. For convenience, of course, it would be better if we used liquid nitrogen instead of liquid helium. However, in order to sufficiently develop the characteristics of sensor and the property of low noise, on the condition of using antenna of a very high angle of elevation, we should put the working temperature as low as possible. At this time the gain band width product is rather large. If the sensor is used for radar it does not need such a low noise level and the temperature may be raised higher. After the temperature has been raised, its water-tightness will be better and this is its advantage. But the value of gain band width product is smaller than that at low temperatures. A good sensor satisfying the practical requirements and working at higher temperatures will not be made until we have new material or a new principle of mechanism. This needs our further study.

Table 3.2

THE BEHAVIOR OF FREQUENCY RANGE SENSORS (78)

Frequency range	400 mega cps to 15 kilomega cps
Gain	20 to 40 db
Band width	0.1% to 1.0% of central frequency
Tuning range	10% to 20%
Noise temperature	20% - 100%
Kinetic range	100 db

(continued)

* Electronics, Nov., 1961.

wave structure as an experimental tool in researching paramagnetic resonance has the following advantages:

i. Although the sensitivity of the slow wave structure is worse than that of a resonance cavity, it is not as bad as we thought. To increase the slow wave factor, we can increase its sensitivity.

ii. When using a more simple equipment, we can have a very wide band width without any adjustment. A helix structure can have a 5:1 band width and comparatively high sensitivity. Comb structures and zigzag structures have a narrower band width but more sensitivity. When these structures are used, it is the most convenient to use a returning wave tube as the stimulating source. By using a travelling wave spectroscopy we can do: linear problem research, group frequency adiabatic fast process research, spin diffusion research, and cross relaxation research. When two or more different frequency signals act on the same specimen and output to different receivers, it is more convenient to use the slow wave structure for experiments.

iii. Measurement will be simpler.

iv. An even circularly polarised radio-frequency field will be produced in a larger region.

v. A strong radio-frequency field will easily satisfy the saturation condition.

c. Methods to increase working frequency:

Recently there have been at least four methods being researched to increase working frequency of solid masers: 1 - Using mechanism of cross-relaxation(63a). 2 - Resonance stimulation. 3 - Pulse field working. 4 - Light stimulation.

Generally the stimulating frequency of a solid maser is about 2 - 10 times higher than that of microwave signal frequency. When the signal frequency is higher than 20 kilo mega cps it cannot be done since there is no stimulating source in the region of the millimeter and semi-millimeter waves. According to the different requirements, we are able to use the aforementioned methods to solve this problem.

By using a cross-relaxation effect, the signal frequency of maser can be stimulated to a higher frequency. Many ideas about this were suggested. One of these ideas is shown in Figure 3.1.7. A stimulating signal raises energy level 1 of a particle to energy level 3, and then down to energy 2 through a non-radiation fast transition. The stimulating frequency then raises energy level of the particle to energy level 4.

When there is an incoming signal with a frequency equal to the interval frequency between energy level 1 and energy level 3, the particle will drop from energy level 3 to energy level 1 and amplification thus can be done. Notice that here the interval between energy level 1 and energy level 3 is equal to the interval between energy level 2 and energy level 4. This will be done only when relaxation times between energy levels satisfy the following relation, i.e., $T_{34}, T_{12} > T_{23}$, then the number of particles of energy level 2 will be larger than that of energy level 1 particles ($n_2 > n_1$). Therefore, how to minimize T_{23} is the main problem. The method of recent research is that crystal is mixed with an impurity of a paramagnetic material which has short relaxation time and will split into two energy levels with an interval frequency ν_{23} under a definite external magnetic field. A practical example is to use Al_2O_3 with two kinds of impurities as substance, the signal frequency 115 KM cps, and stimulating frequency 71.5 MN cps. Another example is "golden red" stone with one or two impurities, a stimulating frequency of 3 cm wave, and a working frequency of 3 cm wave (55). In addition, other experiments are being done using magnesium oxide and other crystals as substances.

Farman wave stimulation (66) requires the substance of maser to have energy levels in a harmonic relation, see Figure 3.1.8. Although the stimulating power is added to a lower frequency interval, it is equivalent to that of a higher frequency interval when aided with the stimulating power due to the existence of the cross-relaxation of spin harmonics with the higher frequency interval. The practical example: stimulating signal 9.545 KM cps, working signal 10.590 KM cps, the substance still ruby, and the adjustable region as 420 mega cps (55). Furthermore, we have suggested a better method (56).

The reason why frequency increases in a pulse field is that the energy levels of a crystal will split due to the strong magnetic field, see Figure 3.1.9 (67). The low frequency of the paramagnetic material is stimulated, then swept by a strong short pulse field ($t_p \ll t_r$). From the pulse field, energy will be absorbed to split the line and increase the output frequency to ω_1 . This method cannot work for a continuous wave. It is its disadvantage. In using ruby as the substance, we obtain an amplified signal up to 300 KM cps, the magnetic field $H = 100,000$ gauss.

d. Experiments of solid masers and their applications (57, 68);

Since 1953, experiments have been done on solid masers of different wave regions for different purposes. Generally speaking, they have brought good results. The superiority of the extremely low noise level of solid masers has been confirmed and used practically. Experiments and applications have the following three divisions:

(1) Radioastronomy (60-74),

Solid masers of the meter wave and centimeter wave regions have been used to receive radio signals reflected as far as Venus. The round trip for the signal takes ca. 5 minutes (69-74). A radioastronomical telescope of 3 cm wave with a ruby maser has observed Cassiopeia A and Saturn, and for the first time observed planet-like nebula NGC 6543. The use of an integrating time of 12 seconds recording an up-down curve and detecting a source of antenna temperature of 0.1°K cannot be done by a common radiotelescope (72). In the 21 cm wave band a ruby maser was also used to observe nebula M33. This maser had an automatic gain control and its gain stability can be $\pm 0.1\%$ within half an hour (73).

(2) Radar (75, 74-78),

Ruby masers have been used with meteorological radar of 3 cm wave band, continuous wave Doppler radar, and aeronautical tracking radar. The last one has been used to trace a flying body at a distance of 120 km and to observe an equal ion cone, diameter 13 cm, discharged from the tail of the flying body. There was an experiment to use ruby maser as a pre-amplifier for 10 cm radar. Some research units have used millimeter wave band masers with 8 millimeter radar. Figure 3.1.10 shows a ground radar equipped with a maser. In order to sufficiently develop the superiority of the low noise of masers, a specially designed antenna is required. The closer the maser and the antenna are, the better the result. Figures 3.1.11 and 3.1.12 show, respectively, small 3 cm wave band masers of open-tube of liquid helium and of a closed liquid helium recovering cooling system (78). A 3 cm wave band radar with maser will have a 1.2 times distance response (75).

(3) Communication (79-82),

In its global communication echo plan, America uses solid masers as receivers of high sensitivity. One of the communication experiments is going on between California and New Jersey. The distance between these two states is 3,000 km. A satellite (a 30-cm-diameter plastic sphere covered with aluminum) is used as a reflector to reflect the signal from transmitting station to receiving station. The communication experiment is successful.

(4) The present problems

A series of problems appear in experiments and applications of solid masers. Some of them have their solutions and some of them require further study. The main problems are:

* Electronics, Nov., 10, 1961.

i. In radio-astronomy, the required higher long-time stability is obtainable from some methods; for instance, to use the unsaturated effect of masers and an iron-oxide adjutor to control stimulating source. These methods are very complicated and need simplifying.

ii. The problem when the radar receiver is too large, loss of power from the gaseous receiving-transmitting switch tube causes the abnormal work of the paramagnetic crystal due to saturation. The loss of power can be divided into tip loss and flat loss. The latter is important⁽⁷⁵⁻⁷⁷⁾. Although many methods try to solve this problem, and flat loss has been lowered to 10^{-8} - 10^{-9} watts, there is still no successful solution. The methods to eliminate saturations in the point of view of quantum electronics are worthy of study⁽⁶⁵⁾. Other practical methods such as the use of iron-oxide for switches⁽⁷⁵⁾ amplitude-limiters⁽⁸⁶⁾, etc., have some disadvantages: increased insertion loss, higher system noise, and decreasing sensitivity of receiver, etc. Hence, how to improve the instruments is very important. In addition, there is the possibility of using a semi-conductor switch and amplitude-limiter⁽⁸⁷⁾.

iii. Masers themselves have the property of very low noise of ca. 10°K . To make them sufficiently useful it would be better to use them for receiving external signals with corresponding noise. In other words, when a receiver of maser is used, the noise received from the antenna should correspond to the noise of the receiver itself. The noise received from antenna varies with the angle of elevation. The larger the angle, the smaller the noise⁽⁸⁸⁾, see Figure 3.1.13. Therefore, masers are fit for antenna of special design high angled elevation. That means that they would be fit for tracing communication between specially designed antenna and satellites and aircrafts, and communications between earth and the satellites passing by. Furthermore, outside the atmosphere, such as higher than 15 km above sea level, the noise will be much lower, see Figure 3.1.14. In frequency response in the region of about 2 - 10 KMcps, the noise of a specially designed antenna will be lower than 10°K . Above the atmosphere, the noise of frequency in the region of 5 - 10 Kmcps is the lowest. Hence, masers are fit for these frequencies.

iv. In point of the total requirements of masers, such as gain band width product, stability, adjustability, etc., the travelling wave type is much better than the cavity type. The former thus is worthy of study.

v. In point of practical uses, how to minimise the volume is very important. First, a strong magnet of small size is required and the problem of omitting the magnetic field should be solved. Some such problems have been solved. For instance, a permanent magnet weighing only 350 grams can supply a magnetic field of 4,000 gauss⁽⁷⁷⁾. A hollow coil

of a special alloy (such as niobium-tin alloy), at low temperature, can produce a magnetic field due to superconductivity. This has been used in masers of L wave band*. A maser of 3 cm wave card consisting of a small Dewar in which there are a permanent magnet, iron-oxide transformer, and separator, is only 35.6 cm (14") long and weighs below 5.36 kg (11 lb 15) (67). In low temperature environment, first we have to design a durable Dewar flask which can be used for several tens of hours continuously on one filling, and stable in any position so that the liquid never pours out. The liquid surface elevation indicator also needs to be designed properly. Other problems are such as how to supply the cooling liquid automatically and how to prevent the effect of vibration of the liquid surface on the stability of the maser, etc. (90)

The best method of liquid helium supply is to design a small recovered (closed) liquid helium cooler. One recent design weighs only 6.36 kg. For convenience, of course, it would be better if we used liquid nitrogen instead of liquid helium. However, in order to sufficiently develop the characteristics of maser and the property of low noise, on the condition of using antenna of a very high angle of elevation, we should put the working temperature as low as possible. At this time the gain band width product is rather large. If the maser is used for radar it does not need such a low noise level and the temperature may be raised higher. After the temperature has been raised, its water-tightness will be better and this is its advantage. But the value of gain band width product is smaller than that at low temperatures. A good maser satisfying the practical requirements and working at higher temperatures will not be made until we have new material or a new principle of mechanism. This needs our further study.

Table 3.2

THE BEHAVIOR OF RECENT RUMI MASERS (78)

Frequency range	400 mega cps to 15 kilomega cps
Gain	20 to 40 db
Band width	0.1% to 1.0% of central frequency
Tuning range	10% to 20%
Noise temperature	20% - 100%
Kinetic range	100 db

(continued)

* Electronics. Nov., 10, 1961.

(Table 1.2 continued)

Starting saturation	Pulse peak value for low repeat frequency is ca. 10^{-2} watt
Recovering time	ca. 0.1 second
Weight of apparatus (excluding stimulating signal source):	
Inner permanent magnet type (liquid Dewar)	7.5 - 22.7 kg
External permanent magnet type (vacuum Dewar)	45.5 - 227 kg
Stimulating source	11 to 45.5 kg
Open liquid helium Dewar:	
Continuous period	8 to 35 hours
Volume	8.5 - 70 cubic decimeters
Weight	4.6 to 21 kg
Rate of evaporation of liquid helium	0.1 to 0.3 liter/hour
Capacity of liquid helium	2 to 10 liters

Table 1.3

ESTIMATED PROPERTIES OF CLOSED (RECOVERED)
LIQUID HELIUM COOLER

1) Used on the sea level

Cooling power (4.2°K)	0.35 - 1.0 watt
Volume	85 - 255 cubic decimeters
Weight	45.5 to 227 kg
Power consumed	1 to 5 kw

Life (time interval between consecutive repairs)

(a) Cooling machine	1,000 hours
(b) Compressor	5,000 to 10,000 hours

2) Used on high altitude

Cooling power (4.2°K)	0.25 - 0.5 watt
Volume	28.5 cubic decimeters
Weight	15 to 22.7 kg
Power consumed	1 to 2 kw
Life (time interval between consecutive repairs)	1,000 hours

2. Gaseous lasers:

The principle is as same as for a quantum amplifier using light stimulation, for example, using ultra-violet from a discharge tube to stimulate hydrogen. This kind of laser can work at room temperature and used as a microwave amplifier, oscillator, or modulator. The reflection on the LiF plate at Brewster's angle can be used to produce linearly polarized light. In order to get circularly polarized light from linearly polarized light, we use a LiF Fresnel prism. Wave length of stimulating signal is 1,240 Å. Working signal is 4 Kc cps. Resonance cavity works on H₀₁₁ mode. The present problems are: gain too small, band width too narrow, and loss in LiF plate too large, etc. The above only mentioned a laser using hydrogen atoms. We need further research on this problem.

D. Quantum modulators (15, 41)

For systematic use of lasers we need high efficiency modulators and detectors. When the usable band width is 1 Kc cps, the primary method commonly used is the Kerr cell method. To use a common photoelectric cell system, the detecting wave has a still low efficiency. Recently there have been many researches on the light modulating process. If some method is used to control the amplitude and frequency of the light amplifier, for the transmission end of a light communication system, the changing magnetic field can change frequency and the inner modulation.

process is only effective in a narrow region. Amplitude modulation or pulse modulation are possible theoretically, but the recently used light stimulating sources cannot be used for milli-microsecond modulation. Some author suggested the use of two quantum amplifiers connected in series for amplitude modulation. The magnetic field of the first amplifier is varied to modulate frequency in a small range. Its output is used to stimulate the second amplifier. A small variation of stimulating frequency will complete the amplitude modulation of second amplifier. In many amplitude modulation processes, most suggest using an external amplitude modulation method. For this process many workers study many different kinds of Kerr cells. Ruby, ethyl neodymium sulfate, and other paramagnetic crystals can also have the Faraday effect. The magnetic field or microwave field can rotate the polarized surface of the transported light. Some author suggested this method: The cross-relaxation of ruby in liquid helium should affect the modulation signal of high frequency. But only a very small rotation was observed. Others suggested that the spin lattice relaxation of crystal grew from ruby and water solution to produce rotation. The rotation observed is 100° , but the magnitude of frequency response is only 100 cps. In addition, using the reflection coefficient of external modulation Kerr cell, when light sweeps this material the frequency will change. An intrinsic difficulty is that the reflection coefficient only changes a few percent, thus the variation of frequency decreases proportionally. Some people thought that the possible solution is to use isoelectric material. When light passes a quickly-produced and quickly-extinguished isoelectric material, the reflection coefficient changes from gas to isoelectric state a few percent. But it is difficult to control an isoelectric material at mega cps frequency. Another suggestion is to use a fast-moving isoelectric current reflecting light, then the frequency will change due to the Doppler effect. In changing isoelectric current velocity to beat frequency the light passes through or is reflected by the isoelectric current. The modulation is frequency-modulation. In addition, some authors suggested that passing spatial modulation, the wave will have the more stable properties of narrow band and directivity. In an ideal case, using time modulation we can have a precise image instantly transferred by the spatial modulation method. See Figure 6.1. A thin semi-conductor screen, which is local, transparent, and swept by electrons, is used to spatially modulate light beams. Recently other countries have made such a "light valve" used for infrared sweeping systems. If other material is used we can design a light valve with light frequency. Another possibility is to use a thin beam photon amplifier. Many thin beam quantum amplifiers at the same time can transfer an image obtained from a cathode ray oscilloscope or a camera to a comparatively far distance. A thin quantum amplifier can also be used at the receiver.

E. Light wave detectors and quantum counters (15, 41)

Some people suggested using a light difference beat to detect light waves, and estimated that a signal at 10^6 km will be received. In this system a quantum amplifier is used as a local oscillator. This oscillating signal will mix with a modulating signal from a quantum amplifier at a great distance. Both frequencies will be mixed in a square-law photoelectric cell and produce a microwave differential beat. This beat will be amplified with a superheterodyne circuit, see Figure 5.1.

Recently, there have been some experiments on light mixing frequency of ruby quantum amplifiers. They use cathodes of a travelling wave tube as mixer, and the helix part as intermediate frequency amplifier. This kind of experiments are of important significance on microwave modulation light communication (92).

"Bird" (supposedly noiseless infrared detector) is a wave detector of quantum system. This kind of quantum counter actually is a binary energy level quantum amplifier. It is designed so that the output is obtained only when a quantum of required frequency is detected (Figure 5.2). A quantum counter suggested by N. Bloembergen is used for the range of infrared $2 - 3 \mu$. Light is stimulated by a mercury vapor lamp, and the output is 6100 Å. The materials used for quantum counters recently under experiments are, for instance, NaCl mixed with PrCl_3 . Another possible material is GdCl_3 . Electronic beam stimulating helium is a basic process for another quantum counter.

F. Quantum Magnetometers (15, 93)

Using quantum electronics we can design a magnetometer with a higher accuracy and sensitivity than we ever had before. As a matter of fact, in principle, the quantum magnetometer and atomic frequency standard are the same, i.e., to change the magnetic field measurement problem into a frequency measurement problem. Quantum magnetometers are of two kinds: (1) proton-precession type, (2) light-stimulating type. The latter consumes little power consumed, and has more sensitivity. The magnetometer and the frequency standard of light-stimulating and atomic frequency standard have a basic principle of proton or electron precession. Different working material and different magnetic field intensity produce different precession frequency. In an instrument of light-stimulating, this precession has its practical significance, because it stimulates the absorption of stimulating light for working material. This effect is applied to the rubidium magnetometer. For example, a rubidium vapor bubble is stimulated by a circularly polarized light emitted from a similar rubidium vapor lamp. This light corresponds to the absorption

line of rubidium, 7947 \AA . The absorption of this light decreases with increasing direction. When the direction is complete, light transfer has maximum value. If a correct frequency signal is added, (about 700 mc/gauss), electronic precession in the rubidium vapor appears and the absorption of polarized light at this frequency is amplitude-modulated. The modulated signal will go back to rubidium vapor, after being detected by photoelectric cell and amplified, to maintain the precession. Since the magnetic field determines precession frequency, it is thus convenient to measure the magnetic field. Using a rubidium vapor magnetometer we can measure magnetic field intensity of a variation smaller than 10^{-6} gauss . When it is loaded in a rocket, it can measure 10^{-6} gauss .

A magnetometer of helium type instead of rubidium vapor type has been designed.

By using small magnetometer to survey space we can draw interstellar pictures.

Conclusion

In addition to the aforementioned quantum radio instruments, which need further improvement, theories of quantum electronics and materials and techniques of quantum instruments are the important compositions of this new science. Since quantum electronics is a combined margin science with bases on spectroscopy, wave spectroscopy, radio-electronics, and paramagnetic physics, its theoretical work and basic research are related to these fields. However, the method of research and point of view are different from these latter sciences. After the second meeting on quantum electronics held in United States in March, 1961, the content of quantum electronics had been increasing with new topics such as the Mossbauer effect, Compton radiation, and superconductive tunnel effect, etc. One of the key problems for successfully designing quantum instruments is to find out a material satisfying a certain requirement and its technique process. Materials include solids and gas, etc. Technological processes include preparation, growth of crystals, defects detection (such as x-ray exposure, neutron exposure, and electron bombardment), determination of crystal axes, cutting, grinding, producing of gaseous vapor, and purifying. One of the effective tools for studying materials of quantum instruments is the mass spectrometer. Therefore, to study producing this kind of instruments is also an important work. How to produce such instruments is beyond the scope of the present paper.

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**AN IN-VIVO OBSERVATION OF INTERCELLULAR PROTOPLASMIC
MOVEMENT IN THE HIGHER PLANTS**

Following is the translation of part of an article by Lou Ch'eng-hou (1236 2052 0683), Peiping College of Agriculture, Wu Su-hsuan (0702 4790 5503), Peiping Institute of Botany, and Chang Wei-ch'eng (1728 0251 2052), of the Hsi-ning Institute of High Plateau Biology. This article, based on two papers presented to the Cytology Conference in Peiping 2 August 1962, appeared in the Chinese-language periodical K'ue-hsueh T'ung-pao, Peiping, No. 12, 1962, page 52.

The phenomenon of nuclear transudation from one cell to another has been observed in the vegetative cells of higher plants, such as the epidermis of tender onion sprouts, as well as the germinal cells, such as the pollen spermatogonia, for more than 60 years. Over 200 articles dealing with this phenomenon have appeared in the journals of China and other countries. Unfortunately none of them have contributed to an understanding of this phenomenon other than a straight observation. Consequently the progress of research on this problem has been slow, and has never attracted the serious attention of botanists. The fault is partly due to the fact that all these observations were made on the fixed and stained specimens, in which the nuclear transudation was often found as an artefact as a result of pressure and injury inflicted on the cells during the processing. For this reason, many authors consider nuclear transudation as an uncommon abnormal finding without any physiological significance.

Since 1955, we have carried out a systematic observation of the nuclear transudation during the entire development of onions and scallions by making blocks and paraffin sections of these plant tissues so as to minimize the effect of processing. We are convinced that nuclear transudation is a natural phenomenon occurring at a certain stage of the plant development, and it has a great deal to do with the transfer of the cellular matter of the plants.

Those two opposing interpretations of nuclear translocation, artefact vs. natural occurrence, have drawn their own exponents. Some of them believe that it is futile to rely only on the dead stained histological sections to understand the physiological process. To support this viewpoint, we have attempted to make a direct observation of the protoplasmic movement between the cells of a living tissue, and our preliminary success has been reported. Recently we have had some new development in this in-vivo observation, and have begun the study of the physiological mechanism of protoplasmic movement. Although some new artefacts may be created by this method of study, this approach will certainly clarify the following points: whether the intercellular protoplasmic movement is a natural phenomenon or an artefact; whether it is possible under proper conditions, to make a direct observation of this movement in the living tissue of higher plants; whether this phenomenon is closely related to the normal physiology of plants.

The following is a brief report on the artificial induction and in-vivo observation of intercellular protoplasmic movement in some higher plants. A more detailed report will be prepared separately.

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